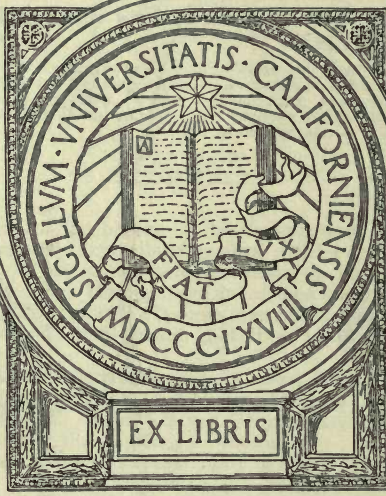
QUIZ-COMPENDS

HISTOLOGY

RADASCH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HISTOLOGY

RADASCH

BLAKISTON'S ? QUIZ-COMPENDS ?

A COMPEND

OF

HISTOLOGY

BY

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SECOND EDITION, REVISED AND ENLARGED
WITH ONE HUNDRED AND SEVEN ILLUSTRATIONS

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THIS VOLUME IS AFFECTIONATELY DEDICATED

PREFACE TO SECOND EDITION.

The call for a second edition has made it possible to make changes and additions in the text.

In the Circulatory System additions were made, among the most important of which are the Bundle of His, Hemolymphnodes and the Parasympathetic Bodies.

Part of the chapter on the Nerve System was rewritten and several cuts were added.

In order to make this book of greater use to the dental students, the Histology of the Tooth was rewritten and enlarged upon, and a new chapter on the Development of the Face and Teeth, with appropriate cuts, was added.

The writer desires to thank the teachers and students who have seen fit to use this work, and he hopes that the present edition will meet with the same satisfaction.

914 South Forty-seventh Street,
Philadelphia, *October*, 1909.

PREFACE TO FIRST EDITION.

It has been the author's purpose to supply a volume more complete than the existing compends, and yet not so voluminous as a Text-book. An effort has been made to present the matter in a clear and concise manner, and as up-to-date as possible.

The subject of Embryology has been touched upon only in so far as it bears directly upon the Histology.

The chapter on Technic has been made as complete as is necessary for routine histologic and pathologic work. The Connective Tissues have been grouped in what seems a simple and also characteristic manner. The Blood Cells have also been arranged in a simple and readily-comprehended form.

The chapter on Placenta and Umbilical Cord has, however, been written somewhat in detail, as the embryology of these organs is essential for a thorough knowledge of their structure. The illustrations are from the works of Prof. Minot, to whom the writer is indebted for their use.

The forty-seven new cuts were prepared under the direction of Dr. H. H. Cushing. Of these, twenty-seven are from slides, while the remainder represent modifications of current Text-book figures.

The writer desires to thank Dr. R. C. Rosenberger for his assistance in proof-reading and suggestions, and the publishers for their many kindnesses and courtesies.

914 South Forty-seventh Street,
Philadelphia.

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COMPEND OF HISTOLOGY.

CHAPTER I.

TECHNIC.

For a thorough understanding of Histology a knowledge of **Technic** is requisite, as sections for study must be properly prepared, and this requires skill and care.

The various steps necessary to prepare a piece of tissue for sectioning are **Fixation, Dehydration, Clearing, Infiltration** and **Blocking.**

FIXATION.

Fixation is the process by which the intercellular substance and the protoplasm of the cells are coagulated by the aid of solutions, thereby keeping them as nearly like normal as possible. Such solutions are FIXING FLUIDS, of which there are a great many combinations. Simple fixatives, which are not numerous, will be given first, and under each, its combinations.

For fixation, one-quarter inch cubes or slices of organs, one-eighth inch thick and cut at intervals, are the most satisfactory.

1. **Heidenhain's Solution** consists of a saturated solution of bichlorid of mercury in a normal salt solution.

Bichlorid of mercury	112 gms.
Sodium chlorid	5 gms.
Water	1000 c.c.

Add the bichlorid to the hot salt solution and when dissolved set aside to cool. The excess of bichlorid will crystallize and keep the solution saturated.

Three to 5 per cent. of *glacial acetic* acid aids the penetration of the bichlorid and assures more thorough fixation.

This solution requires from two to four hours to fix one-half-inch cubes.

2. **Potassium Bichromate.**—This salt in a solution of 3 1/2 per cent. strength is a good fixative and hardener. The strength is gradually increased 1/2 of 1 per cent. by frequent renewal, to 6 *per cent.*, in the course of six weeks. It will not injure tissues left in it for a longer time. It is not often used alone but in combinations mentioned below.

a. **Zenker's Fluid** is a mixture of *Müller's fluid* and bichlorid of mercury.

Müller's fluid	1000 c.c.
Corrosive sublimate	112 gms.
Mix and add before use	
Glacial acetic acid	50 c.c.

This solution requires from twelve to twenty-four hours to act and should be freshly prepared each time before using.

b. **Tellyesnicky's Fluid** consists of a 3 per cent. solution of potassium bichromate to which is added 5 per cent. of glacial acetic acid (5 c.c. per 100). It is allowed to act twelve to twenty-four hours and then the tissues are thoroughly washed and dehydrated. Nuclei are better preserved by this solution than by the usual bichromate mixtures.

c. **Müller's Fluid** depends upon potassium bichromate for its action. Penetration is aided by sodium sulphate.

Potassium bichromate	60 gms.
Sodium sulphate	30 gms.
Water	3000 c.c.

This solution requires from three to six weeks for fixing, but a longer time does not injure the tissues. It is com-

monly used in the dark, and renewed as often as it becomes cloudy.

d. **Kopsch's Fluid** is a combination of potassium bichromate and formalin.

Potassium bichromate (3.5%) . .	80 parts.
Formalin (40%)	20 parts.

The tissue remains in this solution for about twenty-four hours, and is then transferred to a 3.5 per cent. solution of potassium bichromate for three or four days. It should then he thoroughly washed and dehydrated. This solution is especially adapted to the nerve system.

Other combinations of this class are **Orth's, Erlicki's** and **Bensley's** solutions.

3. **Chromic Acid** is generally used in .1 to .5 per cent. solutions, and should be allowed to act one to eight days, as it penetrates slowly. It is especially adapted to connective tissues and where mitotic figures are to be studied.

4. **Osmic Acid.**—This reagent is used in .1 to 1 per cent. solutions as well as in combination with others. It is a specific reagent for adipose tissue, but if turpentine or alcohol-ether is used for clearing the osmicated fat will be removed. The time for fixation depends upon the strength, usually from twelve to twenty-four hours for 1 per cent. solutions.

a. **Flemming's Solution:**

Osmic acid (2% solution)	4 c.c.
Chromic acid (1% solution) . . .	15 c.c.
Glacial acetic acid	1 c.c.

This is the stronger solution recommended by Flemming.

This solution which fixes the tissues in from one to two days, although a longer time will not injure them, should be changed at least once. The tissues are then thoroughly

washed and dehydrated. This fluid, which is good for the study of mitotic figures, should be prepared just before using, as it does not keep.

b. **Golgi's Solution:**

Osmic acid (2% solution)	2 parts.
Potassium bichromate (2 to 2.5% solution) . .	8 parts.

Harden for three days in this solution and impregnate with silver nitrate solution. This is used to stain nerve cells and their processes and glial cells. For farther step see p. 17.

5. **Formalin** is a saturated solution of FORMALDEHYDE GAS in water. It is not used in full strength, but usually as a 4 to 10 per cent. solution. A 10 per cent. solution is prepared as follows:

Formalin	10 c.c.
Sodium chlorid (5% solution) . .	90 c.c.

This requires from twelve to twenty-four hours for its action, and is especially useful in the nerve system. It may be used with potassium bichromate as above given.

6. **Nitric Acid** is used as a 3 *per cent. solution*, and small pieces of tissue are allowed to remain therein from one-half to one hour. Large specimens (embryos) require from four to eight hours. After fixation the tissues are immediately transferred to 70 per cent. alcohol.

It is especially adapted to connective tissues, ova, and embryos.

7. **Alcohol.**—There are several strengths of alcohol suitable for fixation. Besides acting as fixatives they at the same time dehydrate.

a. **Absolute Alcohol.**—This should be of at least 99.2 per cent. strength. It acts very rapidly and thoroughly, but

its expense prevents its routine use. It must be changed several times. After twenty-four to forty-eight hours the tissues are ready to be cleared.

b. **Ninety-five Per Cent. Alcohol** acts in the same way as the above, but some (Mallory and Wright) hold that shrinkage results if any solution weaker than the absolute alcohol is used. This strength has, however, yielded good results in the nerve system. It must be frequently renewed.

Tissues that have been fixed in solutions containing either *osmic acid* or *chromium salts must be thoroughly washed* before dehydration. Golgi's method of staining is an exception, as will be seen when its steps are considered.

Blood spreads are readily fixed in a solution of equal parts of **absolute alcohol** and **ether** in which they are allowed to remain from twenty minutes to an hour. Another good fixative is **absolute alcohol,** nine parts, and **formalin,** one part. The time for fixing is about the same.

The blood spreads may be subjected to a temperature of 120° C. for twenty minutes. Ehrlich prefers this method of fixation to the above.

DEHYDRATION.

After the tissues have been fixed in one of the above solutions and washed, they are ready for the second step, that of **Dehydration.**

Dehydration, or **hardening,** is the removal of the water from the tissues, and is accomplished by alcohols of ascending strengths. The tissues are transferred to a FIFTY PER CENT. solution for six to twenty-four hours, unless otherwise directed. This is followed by immersion in a SEVENTY PER CENT. solution for the same time, and then in a NINETY-FIVE PER CENT. solution for at least twenty-four hours.

During this time, the last should be changed once. To insure perfect dehydration, the specimens, after being drained, may be placed in absolute alcohol for twelve to twenty-four hours.

If the following steps are not to be carried out immediately the tissues shall be transferred to a solution of 70 to 80 per cent. alcohol in which they may remain indefinitely.

CLEARING.

After dehydration is completed the tissues are ready for the clearing agents.

Clearing is the process by which the alcohol is removed and an agent that will mix with the infiltration medium substituted. If paraffin is to be used, an *oil* or fluid miscible with both alcohol and paraffin is necessary; if celloidin infiltration is to follow, then a mixture of *absolute alcohol and ether* is used.

For the paraffin method the tissues are removed from the alcohol, drained a few minutes and then transferred, usually to an oil, for twenty-four hours. The oil penetrates the tissues, removes the alcohol, and remains in its place.

CHLOROFORM, XYLOL, and various oils may be employed, among them being *turpentine*, which usually requires twenty-four hours for half-inch cubes.

XYLOL requires from six to twenty-four hours, or until the tissue is transparent.

CEDAR OIL is used as follows: The tissues are first placed in a mixture of *equal parts of cedar oil and absolute alcohol* for twenty-four hours. They are then drained and placed in *pure cedar oil* for the same length of time. If pure oil alone is used, it is changed several times until the tissues are transparent, which usually requires twenty-four to forty-eight hours.

INFILTRATION.

After clearing, the tissues are ready for **Infiltration.**

Infiltration is the process by which the interstices of the tissue are filled with an agent that hardens and allows the tissue to be cut without distortion. There are two important agents, PARAFFIN and CELLOIDIN. GUM may be used for special purposes. The paraffin method will first be considered.

After clearing, the tissues are drained, blotted with tissue-paper, and then placed in a tube of melted paraffin at a temperature a little above the melting-point, usually 50° to 55° C. This is called PARAFFIN NO. 1, and its object is the removal of the bulk of the oil. After twelve to twenty-four hours the tissues are removed to a tube of fresh paraffin and allowed to remain the same length of time. This is PARAFFIN NO. 2, and the remainder of the oil is removed and pure paraffin left in the tissues. The tissues are then ready to be BLOCKED.

By the use of CHLOROFORM, infiltration with paraffin can be accomplished, to great extent, in the cold. The tissues are completely dehydrated with absolute alcohol and then placed in PURE CHLOROFORM to replace the alcohol. This is accomplished when the tissues become submerged, usually four to eight hours. They are then transferred to a warm, saturated solution of paraffin in chloroform, for two to four hours, and then to pure melted paraffin until all the chloroform has disappeared (two to twelve hours).

If delicate structures are to be infiltrated they may be cleared slowly by adding TOLUOL, or BENZOL, drop by drop, to the specimen in absolute alcohol and mixing after each addition. By this method, 2 c.c. of oil can be added to the same amount of absolute alcohol in four to six hours and no shrinkage result. The specimens may then be transferred

to a mixture of absolute alcohol (1 part) and toluol (3 parts) for one to three hours. They may then be placed in pure toluol from one to four hours, the time depending upon the size, one-eighth to one-fourth inch in diameter. From this it may be transferred to a solution of paraffin in toluol for two or four hours, after which more paraffin is added, and the tube transferred to the paraffin-bath, where it remains for an hour or two, and is then cast.

BLOCKING.

Blocking may be accomplished by the use of *leaden angles*, *paper boxes*, or *wooden blocks*. The *leaden angles* are of various sizes and are used in connection with brass plates. These are all cooled in ice-water, quickly dried and the angles put into place. A small layer of paraffin is then run into the mold, and the tissue placed therein, and oriented. The mold is then filled with melted paraffin, and as soon as a scum is formed, the whole is immersed in ice-water, and the angles cautiously removed, so that the water can act upon all sides except the bottom. Unless this is done, the paraffin, in cooling rapidly and contracting, will enclose water bubbles that are unnecessary and annoying. A little skill is required to cast successfully. Usually, by this method, the paraffin remains clear, a condition much to be desired.

If BLOCKS are used, these should be preferably of oak, an inch and a quarter long, by seven-eighths square. The end is carefully and tightly wrapped with a strip of thin paper, forming a *cup* one-half to one inch deep. The specimen is then quickly oriented upon a thin layer of paraffin, and the cup filled with paraffin. It is then set aside and allowed to cool. The enclosed air bubbles rise. The paraffin is usually not clear by this method, but is

made so by placing the block for several days upon paraffin bath. The warmth clears the paraffin.

After casting, the blocks are trimmed, and then ready to be cut with the microtome.

For the **celloidin infiltration** method, FIXATION and DEHYDRATION are carried out in the same manner as for paraffin, but a different clearing agent is used. A mixture of *equal parts of absolute alcohol and ether* will clear tissues in twenty-four hours, at the end of which time they are ready for the celloidin.

CELLOIDIN, OR PYROXYLIN, is used in two different solutions—*thick* and *thin*. The *thick* solution is prepared by dissolving one ounce of the celloidin in a mixture of 150 c.c. each of absolute alcohol and ether. It is best to soften the celloidin for some hours in the absolute alcohol, and then add the ether. Preserve in a magnesium citrate bottle. The *thin* celloidin is made by diluting the thick with an equal part of the alcohol and ether mixture.

After clearing, the tissues are drained for a few seconds, and then transferred to the thin celloidin for one to four days, and then to the thick for four to seven days. They are then ready to be cast.

The tissues may be blocked, as in the paraffin method, by placing the specimen in a paper cup, as above, upon a wooden, vulcanite, composition, or glass block, and covering with thick celloidin. They are then set aside until a thin scum forms, due to the contact with the air, after which they are placed in 80 per cent. alcohol to harden the celloidin. In twenty-four to forty-eight hours they are ready to cut.

Another way to cast is to place the tissues in low Stender dishes, cover well with very thick celloidin, and orient immediately. When a scum has formed, the dishes are lowered into another containing the alcohol for hardening.

Still another way is to place the tissues with thick celloidin in stoppered paraffin tubes, and, after several days, loosen the stopper and allow the alcohol and ether to gradually escape. When the celloidin has retracted from the sides, the mold is lifted out and placed in the alcohol.

If the celloidin is not hard enough, the blocks may be placed, for twenty-four to forty-eight hours, in eighty per cent. alcohol, containing 1 to 5 per cent. *glycerin*.

The blocks may be hardened without the use of alcohol by placing them in chloroform vapor or pure chloroform until solid.

Gum.—This infiltration medium is prepared as follows:

Syrup	Cane Sugar	28.5 gms.
	Water	30 c.c.
Gum	Gum Acacia	57 gms.
	Water	310 c.c.

Mix together four parts of the syrup, five parts of the gum and to this add nine parts of a saturated solution of boric acid. Filter through muslin.

The tissues are thoroughly washed free of any trace of alcohol, and are then placed in the above solution, and allowed to remain until penetrated, which requires at least twenty-four hours if half-inch cubes are used. A longer time is better. The process is aided by allowing the jar with the tissues to stand in a warm place.

Tissues infiltrated with gum *must be frozen* and cut in a freezing microtome.

After the above steps have been finished, the tissues are ready to be sectioned.

Paraffin blocks are *cut dry*, the knife of the microtome being placed so that it meets the block squarely. When large objects are cut, it is some imes necessary to place the

knife obliquely. Very thin sections may be straightened for mounting by floating them in warm water. The slide prepared with Mayer's albumen (see p. 28) is then dipped beneath them, and if carefully lifted, the section rests smoothly in place thereon.

Celloidin blocks are treated differently. The knife is placed obliquely and *kept moist with* 80 *per cent. alcohol.* The block likewise is kept moist, and as the sections are cut, they are transferred, by means of a large sable brush, to a dish of the same alcohol, and allowed to remain there until required. If the celloidin is too soft, the sections will be quite thick. This may be remedied by hardening the blocks in alcohol containing 1 to 5 per cent. of glycerin. Celloidin answers very well for the nerve system, but where thin sections are desired, the paraffin method is preferable.

DECALCIFICATION.

Bone and teeth may be ground for study. If sections are desired, the inorganic matter must be removed by means of acids. This process is **Decalcification.**

Whole teeth and small pieces of bone are fixed and hardened in solutions containing a salt of chromium, and are allowed to remain as long as required. After being thoroughly washed and dehydrated as above, they are ready for the decalcifying agent, of which large quantities are to be used. The solutions given below are the most important.

1. **Phloroglucin-nitric acid** is no doubt the best. It consists of

Phloroglucin	1 gm.
Nitric acid (concentrated)	5 c.c.
Alcohol (70 per cent.)	100 c.c.

The phloroglucin is dissolved in the nitric acid, and allowed to stand until the fumes have disappeared (about twenty-four hours). The alcohol is then added, and the solution is ready for use. The teeth or bone are placed therein until readily penetrated by a needle or cut with a scalpel. The tissues are then transferred to alcohol and dehydrated in the manner already stated. Celloidin is the better infiltrating agent, as heat tends to harden osseous tissues. Additional nitric acid may be added if desired, but not over 20 per cent.

Mayer's Solution is a 5 per cent. solution of nitric acid in 95 per cent. alcohol. It acts very well. The alcohol is supposed to prevent swelling of the tissues.

Trichloracetic Acid.—A 5 per cent. solution of this is used. It is slower than the nitric acid, but the treatment is the same.

STAINING.

In order to study the various portions of a cell, they must be differently stained. There are three classes of stains; 1, **Nuclear**, 2, **Protoplasmic**, and 3, **Special**; of these two are generally used—NUCLEAR, or BASIC; and PROTOPLASMIC, or ACID. The NUCLEAR stain is used *first*, followed by the PROTOPLASMIC STAIN; this is called counter-staining. Gruebler's products are recommended.

1. **Nuclear Stains.**—The most important of the basic stains are HEMATOXYLIN and the ANILIN DYES.

There are several ways to prepare the hematoxylin. The most rapid is the HARRIS METHOD.

HEMATOXYLIN (HARRIS).

Hematoxylin	1 gm.
Absolute alcohol	10 c.c.
Potassium alum (sat. aq. sol.) . .	200 c.c.

Dissolve the hematoxylin in the alcohol and add it to the alum solution. When this is brought to a boil, add 1 gm. of mercuric oxid, and cool the solution rapidly. The oxygen liberated ripens the solution immediately, and the stain is ready for use when cool. It should be filtered and diluted with three to four times the quantity of water, when ready, and will require three to five minutes to stain.

DELAFIELD'S HEMATOXYLIN is prepared as follows:

Hematoxylin	4 gms.
Alcohol	25 c.c.
Ammonium alum (sat. aq. sol.) .	400 c.c.

Dissolve the hematoxylin in the alcohol, and add this solution, drop by drop, to the alum solution. Expose this to the light and air for a week or more, and then filter. To the filtrate add

Glycerin	100 c.c.
Methyl alcohol	100 c.c.

Expose again for a long time, and filter. This solution must be diluted three to four times, like Harris'.

ACID HEMATOXYLIN is made up as follows:

Hematoxylin	1 gm.	
Absolute alcohol	30 c.c.	
Glycerin	60 c.c.	Saturated
Water	60 c.c.	with alum.
Glacial acetic acid	3 c.c.	

Add the glycerin and water to the hematoxylin, dissolved in the alcohol; then add the acid. This solution must be exposed to the light for three weeks, when it becomes bluish. Sections stained in it are at first not dark, but when exposed to the light, they become bluish.

Most of the ANILIN DYES are not stable, but fade when exposed to the light.

METHYLENE BLUE is used in connection with the nerve system.

METHYL GREEN is used for organs and tissues containing *mucin*, and in blood stains.

SAFRANIN is used for the study of karyokinesis. It should be used upon tissues hardened in Flemming's solution.

Safranin	1 gm.
Absolute alcohol	100 c.c.
Water	200 c.c.

Sections may remain in this solution from two to twenty-four hours and even longer. They are then washed in plain alcohol or carefully differentiated in acid alcohol, and then only the chromatin retains the stain.

BISMARCK BROWN.—This stain is not very soluble in water. A saturated solution is made by boiling the stain in water, and then filtering. This gives a 3 to 4 per cent. solution, which is diluted by adding one-third volume of absolute alcohol. This stains rapidly, but does not over-stain. It is used to advantage in contrast with hematoxylin, in connective tissues and cerebellum. It answers well in staining the *acid cells* of the stomach. The sections should first be deeply stained with hematoxylin, and then subjected, five minutes, to the above stain. The *acid cells* are distinctly *brown*, while the *peptic cells* have a *bluish cast*.

2. **Protoplasmic Stains.**—The more common acid stains are EOSIN, PICRIC ACID, VAN GIESON and ORANGE.

Eosin is commonly used as a 1/2 *to* 1 *per cent.* aqueous or alcoholic solution. It requires one to two minutes, and should be washed off with water, if an aqueous solution has been used; otherwise with alcohol.

PICRIC ACID.—A saturated aqueous solution is used for

15 to 30 seconds. It is then washed quickly with 95 per cent. alcohol.

VAN GIESON consists of PICRIC ACID and ACID FUCHSIN.

Picric acid (sat. aq. sol.)	100 c.c.
Acid fuchsin (1 per cent. sol.) . .	5 c.c.

Stain from one to three minutes, and wash with alcohol. A little stronger solution is used for the nerve system.

ORANGE is used as a 1 per cent. solution, and is employed as a blood stain.

There are stains that affect both nucleus and protoplasm sufficiently to differentiate each well. Such are CARMIN and CARMINIC ACID COMBINATIONS. They are used chiefly in BULK STAINING, especially for entire embryos.

BORAX CARMIN consists of CARMIN boiled in a SOLUTION OF BORAX.

Carmin	2 gms.
Borax (2 per cent. aq. sol.) . . .	200 c.c.

Boil, and then add a few drops of a 5 per cent. solution of acetic acid and 100 c.c. of 70 per cent. alcohol. After a few hours filter, and to the filtrate add a small piece of thymol or menthol, to preserve.

Allow the solution to stain sections for 15 to 20 minutes, and then differentiate with acid alcohol prepared as follows:

Hydrochloric acid (concentrated) .	1 c.c.
Water	29 c.c.
Alcohol (95 per cent.)	70 c.c.

This stain is also used for *bulk staining.*

ALUM CARMIN.—This is prepared by boiling ONE GRAM OF CARMIN with 100 C.C. OF A 5 PER CENT. SOLUTION OF AMMONIUM ALUM. This is filtered when cool, and

preserved as above. It also requires the same time for staining.

PICRO-CARMIN is a DOUBLE STAIN, and its preparation is not so simple. It consists of the following:

Carmin	4 gms.
Ammonia (concentrated)	10 c.c.
Water	200 c.c.

Dissolve the carmin in the ammonia, to which a little water has been added. Then add the water, and, after 24 hours, filter. Allow the solution to stand until most of the ammonia has evaporated and add an aqueous saturated solution of picric acid until precipitation occurs. The solution must be stirred all the time. Set it aside to crystallize and to evaporate to one-third of its bulk. Pour off the liquid and evaporate it to dryness. Dissolve the first crystals and evaporate to dryness. This residue, as a 1 per cent. solution in water, is a very good double stain.

PARACARMIN consists of CARMINIC ACID, ALUMINUM CHLORID, CALCIUM CHLORID and 70 PER CENT. ALCOHOL.

Carminic acid	1	gm.
Aluminum chlorid	0.5	gm.
Calcium chlorid	4	gms.
Alcohol (70 per cent.)	100	c.c.

Dissolve and filter.

This stain is especially useful in EMBRYOLOGY, as it does not overstain, and may be used again and again. On sections, it is a good contrast stain to Weigert's elastica stain.

EHRLICH-BIONDI-HEIDENHAIN STAIN.—This stain is used especially in *blood work* or those tissues containing many *leukocytes*. It is composed of:

Orange (saturated aq. sol.) . . .	100 c.c.
Acid fuchsin (saturated aq. sol.) .	20 c.c.
Methyl green (saturated aq. sol.) .	50 c.c.

This solution is diluted to make a solution of 1–100, which, upon the addition of acetic acid, must be bright red. It is difficult to prepare, and so is better bought ready for use.

Organs should be fixed in corrosive sublimate, and sections stained for 12 to 24 hours, washed with 90 per cent. alcohol, and dehydrated with absolute alcohol, cleared and mounted in balsam.

3. **Special Stains.**—These are used to bring out special structures or tissues. Among these the most important are the **Gold, Silver, Myelin** and **Elastica Stains, Osmic Acid, Sudan III,** and **van Gieson's Stains.**

The **Gold Stain,** used for lymphatic spaces and nerve endings, is not always successful; but when it succeeds, the results are beautiful and gratifying. There are a number of ways of preparing the solution, but the best is the boiling method.

Eight c.c. of a 1 per cent. solution of gold chlorid are mixed with 2 c.c. of formic acid, and brought to a boil, and cooled. This is repeated three times, and it is then ready for use. Small strips (3 to 5 mm. thick) are placed in it for one hour, and the container kept in the dark. They are then washed in distilled water, and exposed to the light in a solution of formic acid (10 c.c. of acid to 40 c.c. of water) for one or two days. They are then dehydrated in 70 per cent. alcohol, and left there for 4 to 8 days or longer.

Silver Nitrate.—Pieces of the nerve system are fixed in the *Golgi solution* (see **Fixatives,** p. 4) and then placed in silver nitrate.

Cajal-Golgi Method.—Thin pieces of nerve tissue are placed in the following solution and hardened for three days:

1.	Potassium bichromate solution (2 to 2.5%)	8 parts.
	Osmic acid solution (1%)	2 parts.

2. Transfer tissues to a solution of silver nitrate of 1/2 to 3/4 per cent. strength. First blot off the bichromate solution and then rinse tissues thoroughly in the some silver solution. Then place tissues in at least thirty times their volume of silver solution and allow them to stand in the dark for three days. Change the silver solution after the first eight to twelve hours.

3. Return to the following solution for one to two days:

Potassium bichromate solution (2%)	20 parts
Osmic acid solution (1%)	2 parts

4. Wash quickly with distilled water and return to a fresh solution of silver nitrate of previous strength for thirty-six to forty-eight hours.

5. Dehydrate in twenty times the bulk of 95 per cent. alcohol for twenty minutes; the alcohol should be renewed after the first five minutes.

6. Dehydrate in same bulk of absolute alcohol for thirty minutes; renew after ten minutes.

7. Replace alcohol by same volume of absolute alcohol and ether (equal parts) for twenty minutes.

8. Transfer to thin celloidin for twenty-five minutes and then thick celloidin for ten minutes.

9. Block and harden in chloroform for about ten minutes.

10. Place for thirty minutes in the following clearing solution:

Carbolic acid (melted)	50 c.c.
Oil of thyme or cedar	50 c.c.
Oil of bergamot	25 c.c.

11. Section, keeping knife and block moist with above clearing fluid.

12. Mount on slides, remove clearing fluid by means of xylol, blot, cover with thick balsam, *but do not use a cover-glass.*

This method gives excellent results.

Silver nitrate is used chiefly for nerve tissues. It may also be injected into the blood-vessels to stain the endothelium, and into the lymphatics to outline the small channels. It has also been used in the liver to outline the bile capillaries.

Myelin Stain.—This is WEIGERT'S HEMATOXYLIN STAIN FOR MYELIN SHEATHS. The tissues are fixed in bichromate, though this is not absolutely necessary. Results are more certain if the tissues have been fixed in a bichromate solution, as they respond more readily to the stains and are not so likely to fade. Celloidin infiltration is usually the best.

After the sections have been cut, they are placed, for four to twenty-four hours, in the following solution:

Potassium bichromate	5 gms.
Chrom alum	2 gms.
Water	100 c.c.

They are then washed thoroughly, and transferred to the following solution for twenty-four hours:

Copper acetate	5	gms.
Acetic acid (36 per cent.)	5	c.c.
Chrom alum	2.5	gms
Water	100	c.c.

Add the chrom alum to the water, bring to a boil, remove the heat, add the acetic acid, and then the copper acetate, stirring thoroughly until the last of the salt is dissolved. When cold the solution should be clear.

This solution is a *mordant*. The sections are carefully washed and carried into the following solution:

Hematoxylin	1 gm.
Absolute alcohol	10 c.c.
Lithium arbonate (sat. aq. sol.) .	1 c.c.
Water	90 c.c.

The sections are stained from fifteen minutes to two or four hours in this solution, and then washed until the washings are clear. They are then differentiated in the following:

Potassium ferricyanid	5 gms
Borax (if granular, use one-half amount)	4 gms.
Water	200 c.c.

In this solution they must remain until the gray matter becomes yellowish. This change must be watched under the microscope. The sections are immediately transferred to water, which is frequently renewed. They are then dehydrated, cleared and mounted in balsam.

The myelin sheaths will be bluish-black.

Weigert-Pal Method.—1. Fix as for Weigert method and after cutting place the sections in a 1/2 per cent. solution of chromic acid for several hours. This step is not necessary if a chromium salt has previously been used for fixation.

2. Wash and transfer to the hematoxylin solution for twenty-four to forty-eight hours.

3. Wash with water containing about 2 per cent. of lithium carbonate. The sections should be bluish.

4. Differentiate in a 1/4 per cent. aqueous solution of potassium permanganate until the gray substance of the nerve tissue is yellowish-brown in color.

5. Transfer to the following solution until the gray substance is almost colorless:

Potassium sulphit	1 part.
Oxali acid	1 part.
Distilled water	200 parts.

This solution requires but a few seconds to produce its action.

6. Wash thoroughly with water, dehydrate, clear and mount.

By this method all the tissues, except the myelin sheaths, are decolorized.

Weigert's elastica stain is used to demonstrate the ELASTIC TISSUE in organs and tissues, and is prepared as follows:

Fuchsin	2 gms.
Resorcin	4 gms.
Water	200 c.c.

This mixture is brought to a boil, and then 25 c.c. of a solution of liquor ferri sesquichlorati added, the mixture stirred and boiled for 3 to 5 minutes. When cool, it is filtered, and the precipitate dissolved upon the filter, in 200 c.c. of 95 per cent. alcohol. This is stirred and boiled until the precipitate is entirely dissolved. The solution is then cooled and brought up to 200 c.c. with 95 per cent. alcohol and 4 c.c. of hydrochloric acid added.

Carbolic acid in the same proportion may be used in place of the resorcin.

Sections should be stained, from 20 minutes to an hour, in this solution, wash well in 95 per cent. alcohol, cleared and mounted.

Osmic Acid.—This is used as a 1 per cent. solution as a special stain for fat, which it turns black and renders almost insoluble in the ordinary reagents used in technic.

Sudan III.—A solution of this stain is also a special stain for fat, coloring it a deep red.

Van Gieson's Stain.—Although this may be classed under the protoplasmic stains, it is, nevertheless, a special stain for white fibrous connective tissue. This it stains a beautiful rose-red, while the other tissues are stained yellowish to brown.

CLEARING AGENTS FOR SECTIONS.

After staining and dehydrating, the sections are to be CLEARED (see Slide Technic, p. 30). The CLEARING AGENT removes the alcohol and prepares the section for the final step of mounting. These agents differ from those used in block technic. When *balsam* or *dammar* is to be used, the sections are cleared with an OIL. Of these, the following are the most important:

CREOSOTE (BEECHWOOD) is one of the commonest and the best for general laboratory use.

OIL OF ORIGANUM is also a very useful clearing agent, and is especially adapted for celloidin sections and those stained with van Gieson's stain. It neither dissolves the celloidin nor renders it stiff.

OIL OF CLOVES acts rapidly, but dissolves celloidin and removes anilin dyes. It does not evaporate, but renders the section hard and sections become yellow with age.

CEDAR-WOOD OIL clears slowly, but has the advantage of not abstracting the anilin dyes.

OIL OF BERGAMOT is very good, but has the disadvantage of removing eosin.

XYLOL, TOLUOL, BENZOL, all act very rapidly, and require dehydration with absolute alcohol. They are useful with anilin stains, and are readily applicable as solvents of balsam. They, however, render celloidin stiff and hard.

CARBOL-XYLOL is a mixture of XYLOL and CARBOLIC ACID.

Xylol	3 parts.
Carbolic acid	1 part.

For larger sections, *i. e.*, brain stem, the writer prefers the following mixture:

Carbol-xylol	2 parts.
Clove oil	1 to 2 parts.

The clove oil keeps the celloidin soft and pliable so that upon blotting the sections are flat and not raised in ridges. It acts very rapidly, and is best for hematoxylin and carmin stains; it does not stiffen celloidin.

ANILIN OIL-XYLOL consists of ANILIN OIL, *two parts*, and XYLOL, *one part*. It is more commonly used than the preceding.

Most of the oils require about *five minutes* to act. The sections are set aside during this time. In the case of rapidly acting agents, the slides are retained in the hand and rocked back and forth until the section is clear. This is usually accomplished in a minute or so.

After clearing, the sections are ready for the final step, that of MOUNTING. There are a number of MOUNTING MEDIA, such as BALSAM, DAMMAR, FARRANT'S SOLUTION and GLYCERIN JELLY.

BALSAM.—Sections to be mounted in balsam must be thoroughly dehydrated and cleared in an oil. The oil is then removed by blotting, a small drop of balsam placed upon the specimen and a clean cover-glass applied.

The balsam is soluble in *chloroform*, *turpentine*, *benzol* or *xylol*. The latter agent is the best. Sections mounted in this medium are permanent.

Dammar is more complex. It consists of the following:

Gum dammar	1½ oz.
Gum mastic	½ oz.
Turpentine	2 oz.
Chloroform	2 oz.

The dammar is to be dissolved in the turpentine, and the mastic in the chloroform. Each is to be filtered, the filtrates mixed and the mixture filtered. This is to be kept in a well-stoppered bottle to prevent the evaporation of the chloroform.

Farrant's Solution.—Sections to be mounted in this medium are neither dehydrated nor cleared, but washed with water and mounted in this solution. It is prepared by adding gum-arabic to a mixture of equal parts of water, glycerin and a saturated solution of arsenious acid. The solution must be filtered after the gum is dissolved, and should have the consistence of a thick syrup.

Preparations mounted in this medium may be made permanent by *ringing*. This is done by running a ring of cement around the edge of the cover-glass.

Glycerin Jelly.—This medium must be warmed before it can be used. A drop is placed upon the specimen, and the cover-glass quickly applied, as this medium sets rapidly. It is used for special purposes, as for *isolated cells*, *urinary casts*, *crystals*, etc. Neither dehydration nor clearing is necessary.

INJECTION.

Injection Masses.—In order to study the circulatory system, the vessels must be injected with a substance that will outline them. For this purpose, either an *aqueous solution of carmin or of Berlin blue*, or *gelatin masses* are used.

Berlin blue is used in water, one part to 20, and this is injected with a *hand syringe* or by *continuous air pressure.* It gives very good results.

The gelatin masses may be either carmin or Prussian blue.

The carmin mass consists of the following:

Carmin	2 gms.
Water.	
Ammonia.	

Stir the carmin in a little water, and add strong ammonia, drop by drop, until the carmin is entirely dissolved. Filter

the solution and add it carefully to the melted gelatin. The latter is prepared by soaking gelatin in double its quantity of water, and melting. The mixture is stirred and then neutralized with dilute acetic acid. If too acid, the carmin will be precipitated, and if the ammonia is not neutralized and the gelatin is quite alkaline, the stain will not be limited to the injected vessels, but will be diffused into the surrounding tissues.

This mass should be filtered while hot, and preserved with a little camphor.

The PRUSSIAN BLUE MASS is somewhat similar. Four gms. of the Prussian blue are stirred into 80 c.c. of water, and the mixture added to gelatin prepared as above. The solution is filtered while hot, and preserved with camphor, or covered with methyl alcohol.

The entire body, or individual organs, may be injected. When the hand syringe is used, great care must be exercised that the pressure be not too great, as the vessels will rupture and the mass extravasate. The *continuous air pressure* method is the better. The mass must be melted and the animal kept warm by immersion in warm water. As soon as the injection is complete, the animal or organ is immersed in ice-water, so that the gelatin may set immediately. When the body is cooled, the organs are cut into blocks, and transferred to 80 *per cent. alcohol*, where they remain until thoroughly hardened, which takes from one to three days. They are then treated with 95 per cent. alcohol to dehydrate, cleared and infiltrated like any other tissue.

Blood is drawn from the finger tip or lobe of the ear. The part is thoroughly cleansed and finally washed with alcohol. A sterilized needle is then plunged to a depth of about one-eighth of an inch, and the blood allowed to flow. The part *should not be squeezed*, as this dilutes the blood with lymph, and causes errors in accurate work.

Blood spreads are obtained by touching a drop of blood with a cover-glass, and immediately placing this upon a second glass. The two are then *slid* apart, so that a *thin film* of blood is present upon each. If the glasses are *lifted* apart, the cells are greatly distorted and useless for study. The spreads are allowed to dry in the air, and then fixed by (1) heat, (2) the absolute alcohol-formalin solution, or (3) absolute alcohol-ether mixture.

If heat is used, the spreads are placed in an oven, and kept at a temperature of 120° C. for twenty minutes. Ehrlich prefers this method.

The alcohol-ether mixture consists of *equal parts of absolute alcohol and ether*. This fixes the spreads in twenty minutes. Results with this fixative are very good.

The alcohol-formalin mixture consists of *nine parts of absolute alcohol* and *one part of formalin*. Spreads are fixed in twenty minutes.

After fixation, the spreads are allowed to dry, and may then be stained like any other tissue. Hematoxylin and eosin give a good result.

Among special stains is the Ehrlich-Biondi-Heidenhain stain. For its composition, see **Stains,** p. 16.

Wright's blood stain is one of the most satisfactory, and is prepared in the following manner:

Steam 1.5 grams of methylene blue in 150 c.c. of a 1 per cent. aqueous solution of sodium bicarbonate for one hour, in a sterilizer. Add a 1/10 per cent. aqueous solution of yellowish eosin to 100 c.c. of the methylene blue solution until the mixture turns purple, and a yellowish metallic scum forms upon the surface, and a blackish precipitate appears; about 500 c.c. of eosin solution will be required, and it should be added slowly, while constantly stirring. The solution is then filtered, the precipitate dried and made into a saturated solution with methyl alcohol. This solu-

tion is filtered and 80 c.c. of the filtrate are diluted with 20 c.c. of methyl alcohol.

Dried spreads are stained for one minute with this solution, and the stain then diluted upon the glass, with water, until the stain is semi-transparent. After two or three minutes, the spreads are thoroughly washed with distilled water, dried quickly and mounted. The acidophilic granules are reddish-lilac and red, while the basophilic granules are deep blue or even black.

This solution both *fixes* and *stains* the cells.

LEISCHMAN'S STAIN is a modification of Wright's. It can be purchased in solid form and is very satisfactory.

EOSIN and METHYLENE BLUE give good results. The spreads are stained in a 1/2 per cent. alcoholic solution of eosin for two or three minutes, using gentle heat. Then they are placed in a saturated aqueous solution of methylene blue for two or three minutes. The spreads are then thoroughly washed, dried and mounted in balsam. As a rule, the granules of the leukocytes are well-stained.

In order to obtain the *bell-shaped red cells*, the finger should be thoroughly cleansed, and the blood drawn as usual. The first drop should be wiped off and a drop of 1 per cent. osmic acid solution placed over the puncture. The blood then flows into the osmic acid, which acts as a fixative, and prevents contact with the air until fixation is complete. If this drop be examined under the microscope, the bell-shaped cells will be seen in great numbers.

BLOOD PLATELETS may also be stained in the above way.

ERYTHROBLASTS of the spleen may be studied in spreads made by drawing thin pieces of the organ over cover-glasses. These are then fixed in the following:

Mercuric chlorid	.78 gm.
Sodium chlorid	.28 gm.
Water	30 c.c.

This solution should be filtered, and spreads fixed in it for one minute. They should then be washed and stained one-half hour with aqueous hematoxylin, washed and covered with a 3 per cent. solution of eosin for two to three minutes. They are then washed, dried and mounted.

Spreads may be stained for three minutes with eosin, and one-half minute with 5 per cent. methylene blue, then washed, dried and mounted.

Rapid Technic.—There is a rapid method of technic that gives good results. The steps are as follows:

1. Fix small pieces in FORMOL-MULLER SOLUTION for eighteen to twenty-four hours. (Formol 20 c.c., Müller's solution 80 c.c.)
2. Place in 95 per cent. alcohol for two hours.
3. Fresh 95 per cent. alcohol two hours.
4. Absolute alcohol ($CuSO_4$), twelve to twenty-four hours.
5. Place in anilin oil at 52° C. until transparent.
6. Place in paraffin at 46° C. for one hour.
7. Place in paraffin at 54° C. for three to four hours.
8. Block.

This method requires about fifty-six hours.

Slide Technic.—The preparation of sections for microscopic study requires skill and care.

Paraffin sections are made to adhere to the slide by means of MAYER'S ALBUMEN. This is prepared by mixing thoroughly *white of egg* and *glycerin* in equal parts and filtering. A very thin film is all that is necessary.

The following desk reagents are sufficient for all ordinary work:

Coplin staining jar, containing *Iodin.*
Coplin staining jar, containing *Kerosene.*
Coplin staining jars, containing *Alcohol. Nos.* 1 *and* 2.
One Barnes bottle, containing *Hematoxylin.*

One Barnes bottle, containing *van Gieson's stain.*
One Barnes bottle, containing *Eosin.*
One Barnes bottle, containing *Alcohol.*
One Barnes bottle, containing *Water.*
One Barnes bottle, containing *Acid Alcohol.*
One Barnes bottle, containing *Creosote.*
One Barnes bottle, containing *Albumen.*
One Barnes bottle, containing *Picric Acid.*

The method of procedure for staining is given in detail below:

1. Cover a clean slide with a thin film of *albumen.*

2. Add a few drops of water, and upon this float the cut paraffin section.

3. Warm gently over a flame, so as to spread the section, but be careful *not to melt the paraffin.*

4. Drain and set aside, or in an oven, for six to twenty-four hours. The slide must be perfectly dry before the other step can be carried out. Put on the slide an identification label.

5. Place in the *kerosene* for five to fifteen minutes, to remove the paraffin. Xylol may be used.

6. Wash with alcohol, to remove the kerosene, and place in the jar of *iodin*, five to ten minutes, *to remove the crystals of bichlorid* of the fixing agent.

7. Remove the excess iodin from the slide with tissue paper, wash with alcohol and place in the *first alcohol* jar for fifteen minutes, to remove the remainder of the iodin.

8. Drain the section, wash with water, cover with *hematoxylin* for three to five minutes, and wash with water to deepen the color.

9. COUNTER-STAIN.—*Eosin* one to two minutes, wash with water to remove excess stain and then alcohol; or,

Van Gieson one-half to one minute, wash with water and then alcohol, as above; or,

Picric acid fifteen seconds and wash with alcohol.

Carmin may be used alone for fifteen minutes, or followed by picric acid, as in the preceding. If carmin is used alone wash the excess off with water and then cover with acid alcohol to *differentiate*. When the color becomes a brick-red, wash the acid alcohol off quickly with ordinary 95 per cent. alcohol and dehydrate in the usual way. Hold the slide in the hand while differentiating.

10. After washing with alcohol, *dehydrate* in the *second jar of alcohol*. Allow sections to remain about five minutes.

11. Clean the slide carefully *without allowing the section to dry*. Blot with tissue-paper.

12. Cover with a drop or two of *creosote for five minutes*. This removes the alcohol, renders the specimen transparent, and allows the use of balsam. This is *sectional clearing*.

13. Drain off the creosote, *blot*, add a drop of *balsam* and cover with a *clean* cover-glass.

14. Remove the identification label, apply a clean one, and write the name thereon.

After the paraffin has been removed, the specimen should *never be allowed to dry*.

The above technic will answer for all ordinary histologic and pathologic work, and, if strictly adhered to, there will not be the slightest trouble in making excellent preparations.

CHAPTER II.

HISTOLOGY.

Histology is the science that treats of the minute structure of normal tissues and organs. Although to the naked eye tissues may have an apparent structure that seems ultimate, when examined under the microscope this structure is seen to be but gross. Each section studied will be found to be composed of minute *elements*, more or less regular, and definitely grouped and arranged. These elements are **Cells.**

A **Cell** is a small mass of protoplasm containing a nucleus. It is the histologic basis of the body, and has a complex structure. Certain parts are absolutely essential for the proper performance of its various functions, while others are accessories, which most cells possess. The parts of a typic cell are:

1. Cell-body.
2. Nucleus.
3. Centrosome.
4. Nucleolus.
5. Cell-wall.

1. The **Cell-body,** or **Protoplasm,** or **Cytoplasm** is a granular, semi-solid substance that constitutes the bulk of the cell. It may or may not be limited by a **cell-wall.** It consists of two main parts, the **Spongioplasm,** or **Filar-mass,** and the **Hyaloplasm,** or **Interfilar-mass.**

The **Spongioplasm,** as its name indicates, is a framework

of comparatively solid structure, in the meshes of which is found the semi-fluid HYALOPLASM. The elasticity of the spongioplasm is said to give rise to ameboid movements.

In the protoplasm are to be seen small darkly-staining bodies, the MICROSOMES, and paler masses, the PLASTIDS.

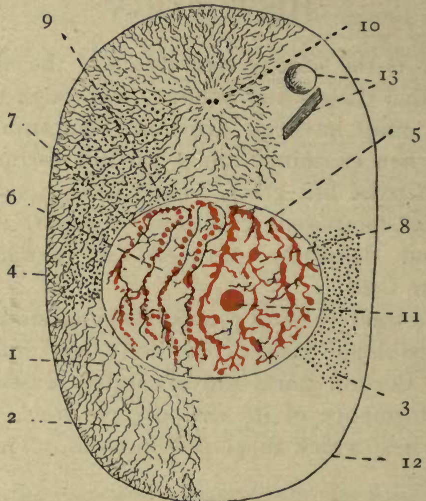

FIG. 1.—SCHEME of a CELL.—Microsomes and spongioplasm only partly sketched (*Stöhr's Histology*).

1. Spongioplasm; 2. hyaloplasm; 3. microsomes; 4. exoplasm; 5. chromatin; 6. achromatin; 7. linin; 8. chromatic knots; 9. nuclear membrane; 10. centrosome; 11. nucleolus; 12 cell-membrane; 13. inclusions.

At the outer margin of the cell-body is a narrow, peripheral zone, containing no microsomes, known as the EXOPLASM. At times there are other structures present, as *fat globules*, *glycogen*, *secretion granules*, *vacuoles*, *pigment*, and *crystals*.

The cell-body has affinity for *acid*, or *protoplasmic*, stains, such as *eosin*, *picric acid*, *carmin*, *orange*, *etc*.

2. The **Nucleus** is usually a darkly-staining body having

a sharp outline, and occupying, as a rule, a central position. In glandular cell, its location varies with the stage of secretory activity. Its structure resembles that of the protoplasm, to a certain extent. It consists of a network and semi-fluid substance, surrounded by a distinct MEMBRANE or WALL. The network is called the CHROMATIN, or NUCLEAR FIBRILS, and the semi-solid substance, the NUCLEAR MATRIX, SAP, or ACHROMATIN.

CHROMATIN is the part of the nucleus that responds to the stains. It is arranged as an irregular network of anastomosing fibrils, each consisting of a delicate central thread, the *linin*, upon which the real chromatin substance is arranged, in the form of granules. Where the chromatin threads cross each other large masses of chromatin at times are seen; these are called *karyosomes*. It is the most important portion of the nucleus during the process of cell-division.

ACHROMATIN, or KARYOLYMPH, is the semi-fluid substance that fills the meshes of the chromatin. It reacts but faintly to stains, and is not of the same importance as the above.

The NUCLEAR MEMBRANE is the wall that limits the nucleus. It is present in nearly all nuclei, stains readily and is perforated for the rapid and easy interchange of fluids. It consists of *amphipyrenin*.

Of the above structures, the chromatin persists throughout all the stages of reproduction, while the remainder of the nuclear constituents disappear.

3. The **Centrosome** is a small, darkly-staining structure, which, owing to its small size, has been found in but few of the cells of the human body. It is readily seen and studied in the ova of some of the lower animals, especially those of *ascaris megalocephala*. It lies, usually, just outside of the nucleus, in a small, clear field called the ATTRACTION SPHERE,

within which are seen delicate lines that radiate from the centrosome. The attraction sphere and the centrosome constitute the ASTROSPHERE.

Besides being the *center of cell-division*, the CENTROSOME seems to play an important part during the resting stage. In pigment cells and white blood-corpuscles, it seems to preside over the movements of the whole cell, and in ciliated and flagellated cells over the action of these processes.

4. The **Nucleolus** is a small body found within the nucleus. It is not always present, and more than one may be found. In nerve cells and ova it is unusually large and readily stained, while in others it is scarcely noticeable. Its importance is doubtful, as no definite function has as yet been found. It consists of *pyrenin*, and disappears during cell-division.

5. The **Cell-wall** is a more or less prominent membrane that limits cells. It is not present in all animal cells, though some hold that even the wandering cells possess a delicate membrane. In some instances, it consists of the differentiated, peripheral protoplasm, and in others, is a secretory product of the protoplasm. When it surrounds the entire cell it is called a *pellicula;* if it is found upon the exposed surface, as in the intestinal cells, it is termed a *cuticular border*.

Of the above structures, the **Cytoplasm, Nucleus** and **Centrosome** are the essential parts, when the important functions of the cell are considered. In red blood-cells the nucleus is absent, and, as a consequence, these cells cannot reproduce themselves.

Cells differ greatly in form and size; the nucleus conforms somewhat to the shape of the cell. Usually but one is present, but in giant cells and voluntary striated muscle, many are to be found.

The cell, like the organism, exhibits a number of proper-

ties, such as **Metabolism, Growth, Motion, Irritability** and **Reproduction.**

Metabolism is the change that takes place in a cell during the performance of its functions. When the result is the formation of complex structures, the process is called ANABOLISM; if destructive, the conversion of complex to simple compounds, the phenomenon is termed KATABOLISM. SECRETION and EXCRETION are anabolic changes, as simple

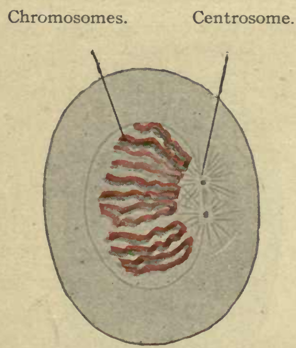

FIG. 2.—SCHEME OF THE CLOSE COIL AND THE DIVISION OF THE CENTROSOMES (*Stöhr's Histology*).

structures are converted into complex compounds. Secretion may be glandular secretion, or simply an intercellular substance may be formed.

Growth is the result of an anabolic process. The cells increase in size, equally or more often unequally, depending upon the organ. When the latter occurs, the cell-form is changed. By such a change in all cells, the organism increases in size, though the amount contributed by each cell may be microscopic.

Motion.—But few cells possess this property to any great extent. The ameboid leukocytes show it best as they may pass from one part of the body to another. One of the most

characteristic examples of this property is exhibited by the muscles, especially the voluntary striated variety; here, although the whole cell moves, the motion is limited to one direction. Motion may be limited to only a portion of the cell, as to hair-like processes called cilia.

Irritability is the property of response to surrounding influences or stimuli. This is more pronounced in the individual cells of such animals that possess no nerve system. Here it is practically a primary change in the cell.

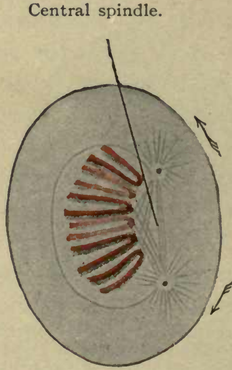

FIG. 3.—SCHEME OF THE LOOSE COIL AND SEPARATION OF THE CENTROSOMES (*Stöhr's Histology*).

When a nerve system is present, this presides over such changes which are then secondary.

Reproduction is the process by means of which a cell or an organism propagates itself and continues its life history. Without this or an analogous process, life would soon cease to exist. It is of two varieties, DIRECT, AMITOSIS OF BUDDING and INDIRECT, MITOSIS OF KARYOKINESIS. Of these, the latter is the more common.

In **Amitosis,** the cell-body is marked by a constriction that gradually deepens and is imparted to the nucleus.

As this deepens, the protoplasm and nucleus are finally divided into two small but practically equal cells, which have the same structure as the parent cell. By growth, these cells, which are called daughter cells, increase in size, until that of the parent, or mother, cell is attained.

This form of division is seen in the bladder epithelium in mammals and in the cells of Sertoli of the testicle.

Mitosis is a very complex process, in which the nucleus plays a very important part. The protoplasm is almost

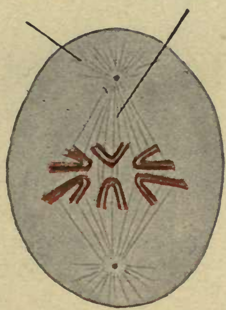

FIG. 4.—SCHEME OF THE MOTHER STAR, OR EQUATORIAL PLATE (*Stöhr's Histology*).

passive until the late stages of the process. The various stages are the PROPHASE, METAPHASE, ANAPHASE and TELOPHASE. These are not absolutely separable from one another. The changes that occur may be grouped under three heads—*nuclear*, *centrosomic* and *protoplasmic*.

PROPHASE.—The *nuclear* changes are quite complex. Whereas the *chromatin* is ordinarily arranged as an irregular network, when division begins the irregular twigs of the network gradually become smooth, and form, usually, a single thin closely-convoluted thread, called the SPIREM, or SKEIN. The thread becomes thicker and shorter,

and soon separates into a number of segments called CHROMOSOMES. This sometimes occurs before the spirem is formed. The chromosomes become U- or V-shaped, and arrange themselves along the equator of the cell with the closed ends directed toward a common center, called the *polar field*. This arrangement is termed the EQUATORIAL PLATE, or MONASTER, and practically ends the chromatin changes during the PROPHASE.

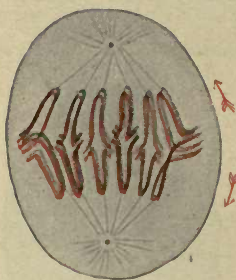

FIG. 5.—SCHEME OF METAKINESIS, SHOWING THE NUCLEAR SPINDLE (*Stöhr's Histology*).

The CHROMOSOMES are always even in number, and the same number is always formed in each cell of the same species. In *man*, the number is said to be sixteen or twenty-four.

The *nuclear membrane*, during these changes, has gradually become more and more hazy, and finally *disappears*. The *achromatin* is released, and mixes with the protoplasm.

The *nucleolus* likewise gradually fades and disappears.

The *centrosome* is the *dynamic center* of the cell. It divides into two portions (if within the nucleus, it passes first into the protoplasm), each of which becomes surrounded by its own *attraction sphere*. These centrosomes gradually move apart, through an arc of 90°, to opposite poles of the cell. During this change, some of the intervening rays remain in

contact, forming a spindle of delicate threads, which is complete when the centrosomes reach their polar position. This is the CENTRAL, OR ACHROMATIC SPINDLE, and the threads are of the utmost importance, and become attached to the chromosomes of the equatorial plate.

With the formation of the equatorial plate and central spindle, the PROPHASE ends. Variations, too numerous to describe, occur, but the above is the usual course in this stage of mitosis.

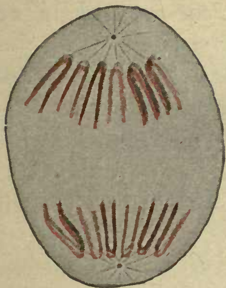

FIG. 6.—SCHEME OF THE DAUGHTER STARS.

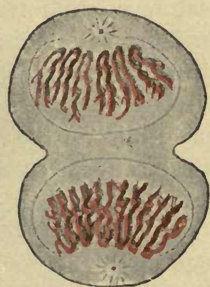

FIG. 7.—SCHEME OF DIVISION OF THE PROTOPLASM FORMING DAUGHTER CELLS.

(*Stöhr's Histology*).

METAPHASE.—This is the stage during which the chromosomes divide and separate. It concerns the chromatin chiefly.

The chromosome *divide longitudinally* into two equal portions. This cleavage occurs at the closed end first, and as it proceeds, the *daughter chromosomes* become separated, one-half being drawn toward the one centrosome, and the other toward the second. This gives rise to a second spindle, the NUCLEAR, OR CHROMATIC SPINDLE. The separation is affected by the traction exerted upon the daughter chromosomes *by the threads of the central spindle.*

ANAPHASE.—This is the stage of complete separation of

the chromosomes. The latter collect around their respective centrosome, and remain connected to the opposite set, for some time, by the central spindle threads. The figures thus formed are the DIASTERS, OF DAUGHTER STARS.

TELOPHASE.—This stage is concerned with the protoplasmic changes and the formation of a resting nucleus. Up to this time, the protoplasm has been practically quiescent.

The chromosomes collect around the centrosomes, and unite to form a *close skein*. Lateral twigs are developed that anastomose to form the *nuclear network*, a *nuclear membrane* is formed and a *nucleolus* appears.

The hitherto inert protoplasm shows changes. A double row of vacuoles appears at the equator of the cell, and separation occurs in the intervening space until two separate masses are formed; these are the DAUGHTER CELLS.

The above changes are usually succeeded by a period of rest.

Although apparently a long process, only about *one-half hour* is consumed in the division of human cells, but the cells of lower animals require a longer period.

In the case of *giant cells*, the nucleus divides and redivides, while the protoplasm remains unchanged. They may also be formed by the fusion of the protoplasm of a number of cells with the retention of the individuality of the nuclei.

As all cells are developed from preëxisting elements, it is but natural that the original cell of the body, the **Ovum,** should be of greatest interest. It is the most characteristic cell of the body, and is secreted by the ovary. It is the largest cell, and illustrates the individual parts well.

The **Ovum** consists of a limiting wall, the **vitelline membrane,** that is well developed. Within this is the protoplasm, **vitellus,** which consists of two parts—the DEUTOPLASM, OR NUTRITIVE YOLK, and the ANIMAL PROTOPLASM, OR FORMATIVE YOLK. This is of importance, *embryologically.*

Within the vitellus is found the nucleus, or **germinal vesicle,** which contains a deeply stained nucleolus, or **germinal spot.** The centrosome is to be seen in unripened ova. After maturation this body disappears. In what might be termed an *embryologic ovum*, there are two layers external to the vitelline membrane, the ZONA PELLUCIDA and the CORONA RADIATA. Of these, the former is the more important, because of the part which it plays in the early stages of development.

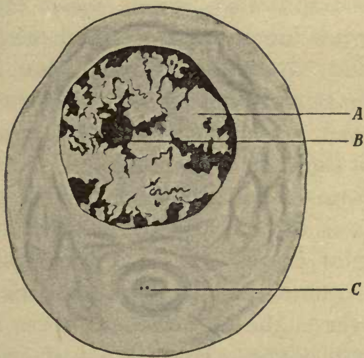

FIG. 8.—UNRIPENED OVUM FROM A YOUNG GUINEA-PIG.
A, Nucleus; *B*, nucleolus; *C*, centrosomes in the attraction sphere.

There are a number of processes that occur in the ovum before it can develop into an offspring. Of these, the most important are **MATURATION** and **FERTILIZATION.** The *former* occurs, usually, in the ovary, and the *latter*, as a rule, in the Fallopian tube.

Maturation is the process by which part of the chromatin and a small portion of the protoplasm are extruded in the form of two minute structures called POLAR BODIES. It is a *modified karyokinesis*, and its object is unknown. All ova must pass through this process before they can be fertilized.

Fertilization is the process in which the male and female elements unite to form a complete and perfect cell, which, by division, gives rise to the cells that ultimately form the whole body.

The **male element,** or **spermatozoön**, or **spermium**, consists of HEAD, MIDDLE-PIECE and TAIL. Of these the HEAD and MIDDLE-PIECE, representing the NUCLEUS and CENTROSOME, *respectively*, of a cell of the testicle, enter the ovum and form *eight* chromosomes.* The chromatin of the germinal vesicle of the ovum also forms *eight.* By longitudinal cleavage *thirty-two* are formed of which *sixteen* enter into each diaster and, consequently, each daughter cell. By this process *the descendants of the fertilized ovum contain double the number of chromosomes that existed in either of the original cells before fertilization.*

After fertilization the ovum divides and redivides, forming an irregular mass of cells called the **Morula,** or **Mulberry Mass.** Certain of these cells form a complete layer that surrounds the remainder, which constitutes an irregular mass. The layer is the OUTER CELL-MASS and the latter the INNER CELL-MASS. This structure constitutes the **Blastula,** or one-layered vesicle. Of these two structures the *inner* is the more important as it persists and forms the whole body while the *outer* is said to disappear.

The INNER CELL-MASS forms two layers, an *outer*, several cells in thickness, the ECTODERM, or EPIBLAST, and an *inner*, composed of but a single layer, the ENTODERM, or HYPOBLAST. This is the **Gastrula,** or **Diploblast.** The ectoderm and entoderm each set aside a number of cells which by multiplication form a third layer, the MESODERM, or MESOBLAST, that lies between the two. This structure receives the name of **Blastodermic Vesicle,** or **Triploblast.**

* Some writers claim the somatic cell contains sixteen chromosomes while others say there are twenty-four.

From these three primitive layers all the organs and tissues of the body are formed as follows:

ECTODERM.

The nerve system (cerebrospinal and sympathetic) the retina, the bulk of the crystalline lens, the muscle of the iris and part of the vitreous humor of the eyeball, the epithelium of the cornea and conjunctiva, the epithelium of the internal ear and of the olfactory organ, the medulla of the adrenal.

The epithelial lining of the anterior portion of the male urethra, the labia of the female and the glands leading thereto.

The epithelial lining of the mouth and salivary glands, epithelial lobe of the pituitary body, the enamel of the teeth, the cells of the nasal tract and glands leading thereto, to the pharynx, and the lining of the anus.

The epidermis and appendages of the skin, muscles of the sweat glands.

The syncytium of the placenta.

ENTODERM.

The epithelial lining of the bladder, the prostate and glands of Cowper, of the first and second portions of the male and entire female urethra, vestibule and glands of Bartholin.

The epithelium of the tongue, thymus and thyroid bodies of the parathyroids, middle ear and Eustachian tube.

The epithelium of the alimentary and respiratory tracts from the mouth and posterior nares down and the epithelium of all glands opening into these structures.

The notochord.

MESODERM.

The vascular system.

The lymphatic system including the large serous cavities, spleen and thymus body (except the corpuscles of Hassal).

The muscle tissues (except the muscles of the sweat-glands and iris).

The connective tissues.

Testicle, vas, seminal vesicles, ejaculatory duct, ovary, oviducts, uterus and vagina.

Kidneys, ureters and cortex of adrenal.

CHAPTER III.

THE TISSUES.

From the preceding table it will be seen that all tissues are developed from the three layers of the triploblast. These tissues are grouped, histologically, under four classes, **Epithelial, Connective, Muscle** and **Nerve.**

A **Tissue** consists of similarly differentiated cells held together by intercellular cement, and performing a definite function. The intercellular substance varies with the different tissues. The cells of a tissue may be so arranged as to form an organ or merely a supporting structure.

Epithelium.

The **Epithelial Tissues** are characterized by the small amount of the intercellular cement. The cellular elements are usually prominent, and rich in granular protoplasm. They are found lining cavities that communicate normally with the air and usually secrete, although they may also have an excretory, absorptive, or protective function. They are avascular and may be derived from any of the layers of the triploblast. The cells very in size, form and arrangement, as will be seen later.

For convenience of description, the cells are classified as follows:

1. **Squamous.**
   a. SIMPLE.
   b. STRATIFIED.
2. **Columnar.**
   c. SIMPLE.
   d. STRATIFIED.
   Modified.
3. **Ciliated.**
   e. SIMPLE.
   f. STRATIFIED.
4. **Prickle cells.**
5. **Goblet cells.**
6. **Transitional cells.**

7. **Pigmented.** 8. **Neuro-epithelial.**
Specialized. 9. **Glandular.**

1. **Squamous.** a. The SIMPLE SQUAMOUS cells consist of a single layer of flattened elements, each containing a

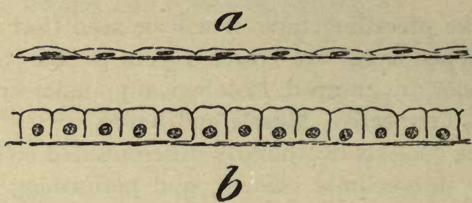

FIG. 9.
a. Simple squamous cells. *b*. Simple cuboidal cells.

large nucleus. This is usually in the center, and has an oval, or round form. They occur in the descending limb of Henle's loop, the capsule of Bowman in the kidney, the

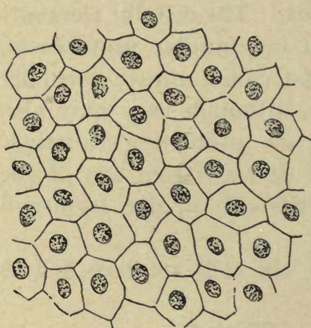

FIG. 10.—SURFACE VIEW OF SQUAMOUS CELLS OF FROG'S SKIN.

FIG. 11.—SQUAMOUS CELL ISOLATED.

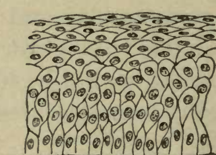

FIG. 12.—STRATIFIED SQUAMOUS EPITHELIUM.

alveoli of the lungs, and in parts of the ventricles of the brain.

b. The STRATIFIED SQUAMOUS variety consists of many layers of cells that are unlike in form. The lowest layer,

the *germinal stratum*, is columnar, while those cells just above are polygonal. The succeeding cells become more and more flattened, forming the squames, or scales, from which this variety receives its name. It is found covering the body as the epidermis, lining the mouth, pharynx,

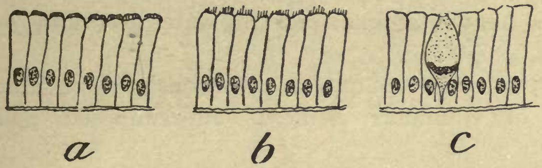

FIG. 13.
a. Simple Columnar showing Cuticular Border. *b*. Simple Ciliated Cells. *c*. Simple Columnar and Goblet Cells.

esophagus, epiglottis, vocal cords and the anus and vagina.

2. **Columnar.** c. SIMPLE COLUMNAR cells are tall, cylindric elements arranged in a single layer. The nucleus is usually oval, and found nearer the base than the center of the cell. The variety is found in the stomach and intestinal tract,

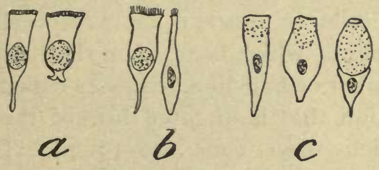

FIG. 14.
a. Isolated Columnar Cells. *b*. Isolated Ciliated Cells. *c*. Three Stages of Goblet Cells.

the penile portion of the urethra, glands of Cowper, and Bartholin, prostate, gall-bladder and seminal vesicles, and in many gland ducts. In the intestine these cells, upon their exposed surface, have a layer of differentiated protoplasm forming a partial membrane; this is called a *cuticular border*. Low columnars are often called cuboidal.

PSEUDOSTRATIFIED cells are simple columnar, or ciliated, cells, in which the nuclei are not all basal, but occupy different levels, thus giving the appearance of several layers of cells, where, in reality, but a single layer exists. These are found as ciliated elements in the oviducts, uterus and middle ear and as non-ciliated elements in the seminal vesicles (maybe simple) and prostate, according to some writers.

d. STRATIFIED COLUMNAR cells consist of a number of layers of columnar elements superimposed upon one

FIG. 15.—PSEUDOSTRATIFIED CELLS.

another. The cells are not as large as the preceding. They occur in the vas deferens, membranous urethra and the ducts of some glands.

3. **Ciliated cells.** e. SIMPLE CILIATED cells are simple columnar elements, which bear, upon their exposed surface, a varying number of hair-like processes called cilia. These possess a motion that is directed toward the outlet of the organ in which these cells are found. They line the smaller bronchioles, spinal canal, accessory spaces of the nasal fossæ and the ventricles of the brain.

f. The STRATIFIED CILIATED cells are practically stratified columnar cells, of which the exposed layer alone possesses cilia. They are found in the epididymis, first part of the vas, Eustachian tube, upper part of the pharynx, in the larynx, trachea and nasal tract.

4. **Prickle cells** are polygonal elements that possess little spines, which project from the sides of the cells. These,

meeting the spines of other cells, prevent the cell-bodies from touching. In this way, a series of *intercellular bridges and spaces* is formed. These cells are found in the epidermis, just above the genetic layer.

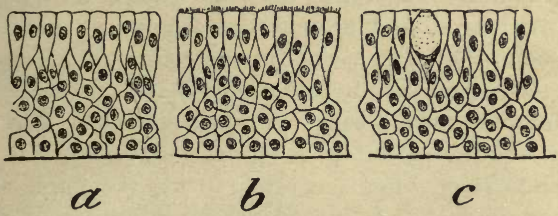

FIG. 16.

a. Stratified Columnar Cells. *b*. Stratified Ciliated Cells. *c*. Stratified Columnar Cells showing Goblet Cells.

5. **Goblet cells** are cells of the cylindric type, distended with a peculiar secretion called *mucin*. When filled, they resemble a goblet, hence the name. When the secretion has been discharged, the cells are long and slender, the part containing the nucleus projecting on either side. Such cells are met with in the gastro-intestinal and respiratory tracts.

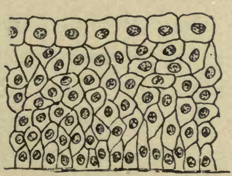

FIG. 17.—TRANSITIONAL CELLS.

6. **Transitional cells** are peculiar stratified elements that are neither columnar nor squamous. They occupy an intermediate position, as all the cells are polygonal. They occur in the pelvis of the ureter, in the ureter, bladder, the

first portion of the male and the greater portion of the female urethra.

7. **Pigmented cells** are polygonal or columnar cells, in which the protoplasm contains a varying number of pigment granules. The former shape is found in the epidermis of colored races, and around the nipple and genitals of Caucasians; the latter occurs in the retina of the eye, and the pigment granules obscure the various parts of the cell.

8. **Neuro-epithelial cells** are epithelial cells that have become so differentiated as to perform a special sense function. They differ according to location, and will be described under each special sense. They occur in the retina (*rods and cones*), in the internal ear (*hair cells*), in the olfactory mucous membrane, in the taste-buds and as tactile cells.

9. **Glandular cells** also vary according to the nature of the gland in which they are found, as in the liver, pancreas, etc.

Mucous Membranes.—The epithelial surfaces within the body are termed **Mucous membranes. Glands,** which are evaginations of such surfaces, are also classed with mucous membranes. Such membranes are complexes of all four varieties of tissues. They are lined by EPITHELIAL CELLS, of any of the varieties above mentioned, that rest upon a delicate BASEMENT MEMBRANE, beneath which is found a layer of fibro-elastic tissue called the TUNICA PROPRIA. Here are seen nerves, capillary blood-vessels, lymphatic channels or spaces, and, in certain organs, glands and lymphoid tissue. The structure is limited, peripherally, by a layer of involuntary, nonstriated muscle tissue, the MUSCULARIS MUCOSÆ. The latter is not always present, as will be seen when the various organs are studied in detail. These membranes line cavities that *communicate normally with the air* and *usually secrete*.

As some writers classify **Endothelial cells** as epithelial, it is well to consider them at this time, so as to contrast them.

Endothelial, or, better, **Mesothelial,** cells are thin, flattened elements possessing a large projecting nucleus. They are irregular in outline, and are held together by inter-

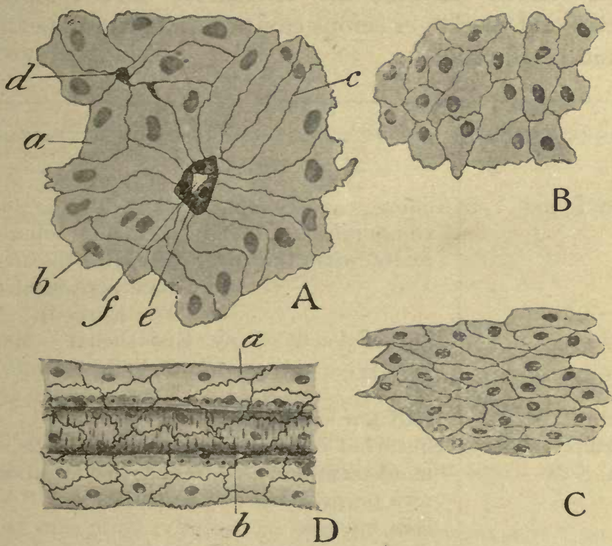

FIG. 18.

A.—ABDOMINAL ENDOTHELIUM. *a.* Endothelial cell; *b.* nucleus of cell; *c.* cell boundary; *d.* stigmata; *e.* endothelial cells of stomata; *f.* stomata. B.—MESENTERIC ENDOTHELIUM. C.—ARTERIAL ENDOTHELIUM. D.—PERIVASCULAR LYMPHATICS. *a.* Endothelial cells of lymphatics; *b.* blood-vessel (arteriole).

cellular cement. They never occur in more than a single layer, and form, with fibro-elastic supportive tissue, the subendothelial connective tissue, a **Serous Membrane.** A **Serous Membrane** possesses *neither basement membrane nor muscularis mucosæ,* and lines cavities that *do not* communicate normally with the air and *never secretes.* Such

membranes are *smooth*, *moist*, *glistening* and *transparent*, and subject to inflammations different from those of the foregoing. Openings called stomata are said to exist, but these are now considered artifacts.

Serous membranes are found lining joint-cavities, bursæ, tendon sheaths, the circulatory and lymphatic systems and the larger serous cavities, the pleural, peritoneal and pericardial.

CHARACTERISTICS.	MUCOUS MEMBRANES.	SEROUS MEMBRANES.
Where found . .	Lining cavities that communicate normally with the air.	In cavities that do not normally communicate with the air (female peritoneal cavity excepted).
Lined by . . .	Epithelial cells of any variety.	Endothelial (Mesothelial) cells, one layer.
Secrete	With few exceptions-	Do not.
Structure	Epithelial cells, basement membrane, tunica propria, muscularis mucosæ.	Endothelial cells, subendothelial connective tissue.
Represents . . .	All four varieties of tissue.	But two varieties (neither muscle nor epithelial tissues).

GLANDS.

A description of epithelial tissues would not be complete without a consideration of **Glands.** Glands may be UNICELLULAR, as the GOBLET-CELL, or MULTICELLULAR, as those that will be considered below. A **Gland** is an evagination of a mucous surface, consists of epithelial cells, arranged in definite groups, and performs a physiologic

function. These groups are the *secretory units* of the organ.

Glands may be classified in several ways: 1, as to **Structure,** 2, as to **Secretion,** and 3, as to **Outlet.**

1. **Structure.**—As the secretory units are of different shapes we have the following divisions and subdivisions:

Tubular Glands.
- Simple.
- Branched.
- Coiled.
- Compound.

Tubulo-alveolar Glands.

Alveolar, or **Racemose Glands.**
- Simple.
- Compound.

Tubular.—Simple tubular glands are mere cylindric depressions in the mucous membrane. They are lined, usually, by simple columnar cells. They occur in the cardiac end of the stomach, and in the small and large intestines.

The **branched tubular** are like the above, except that the lower end is divided into two or more secretory units. The lining cells may be columnar, or ciliated, as in the uterus. These glands are found in the fundus and pyloric portion of the stomach, in the duodenum (Brunner's glands), in the uterus, and in the prostrate.

Coiled tubular glands are really simple tubes, the secretory portion of which has become coiled and convoluted to occupy as small a space as possible. The lining cells are columnar or cuboidal (low columnar). Examples are the sweat and ceruminous glands.

Compound tubular glands are those in which the primtive tubules have divided and redivided until an enormous

number of divisions has resulted. Pure examples of this variety are the liver (also called reticular), testicle, kid-

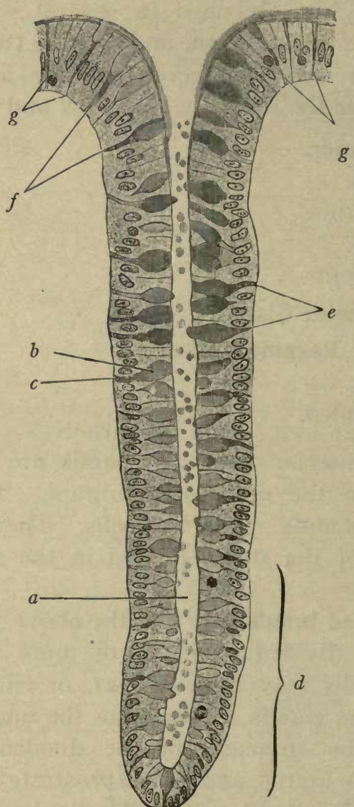

FIG. 19.—GLAND OF LIEBERKUEHN FROM A SECTION OF THE LARGE INTESTINE.

a. Lumen; *b*. secretion of cells; *c*. nucleus and protoplasm of cell; *d* fundus cells at the beginning of secretion; *e*. *f*. goblet cells in later stage; *g*. dying goblet cells (*Stöhr's Histology*).

ney, thyroid, lacrimal and serous glands of the mucous membranes.

Tubulo-alveolar glands are those in which the terminal tubules possess sac-like evaginations along the walls. Such glands are the submaxillary, sublingual, mammary and the lungs.

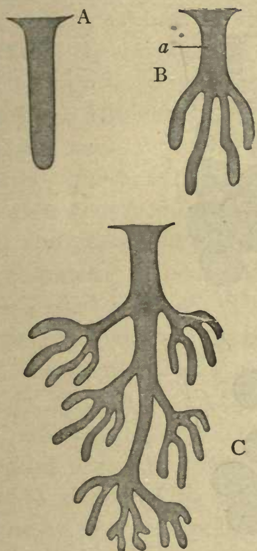

FIG. 20.—DIAGRAMS OF TUBULAR GLANDS (*Stöhr's Histology*).
A. Simple tubular; B. branched tubular; *a*. excretory duct; C. compound tubular.

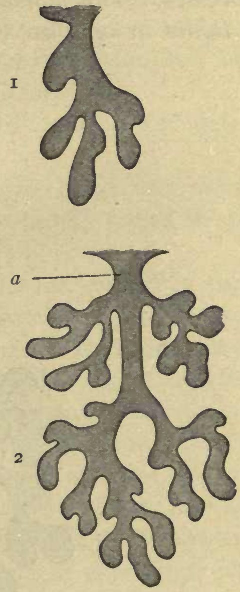

FIG. 21.—ALVEOLO-TUBULAR GLANDS (*Stöhr's Histology*).
1. Branched alveolo-tubular; 2. compound alveolo-tubular; *a*. excretory duct.

Alveolar.—The SIMPLE ALVEOLAR, or saccular, glands are sac-like depressions extending from the free surface. They are comparatively few in number, and occur as the smallest sebaceous glands.

The COMPOUND RACEMOSE glands are like the compound tubular, except that the terminal portions are saccular,

instead of tubular. Such glands are the pancreas, parotid, and the large sebaceous glands.

2. **Secretion.**—The function of a gland is to give rise to a substance to be used by the body in some of its many processes. This substance is called a *secretion*, and it may be *liquid* or *cellular* (ovum). The liquid secretions may

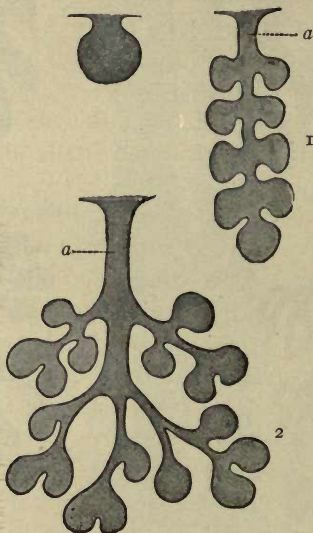

Fig. 22.—Alveolar Glands (*Stöhr's Histology*).
1. Alveolar system; 2. compound alveolar gland; *a*. excretory duct.

be *serous*, *mucous*, or *mixed*. These terms, applied to the respective glands as well, have reference to the salivary glands alone.

SEROUS glands are those which form a thin albuminous secretion. The glandular cells respond well to stains. The parotid and pancreas belong to this class.

MUCOUS glands are those that give rise to a thick viscid substance. The cells here stain but lightly with the

ordinary stains. Such are the small glands found in the mouth, esophagus, trachea and the sublingual, according to some writers.

MIXED glands are those in which both varieties of secretion are formed. The secretory areas are stained darkly or lightly, according to whether they are serous or mucous. The sublingual and submaxillary glands are examples, and of these, the latter is the more characteristic.

The minute structure of these glands will be considered under the **Alimentary Tract.**

The *excretory* glands are the kidneys, lungs and sweat glands. Each will be considered in detail, under its respective system.

3. **Outlet.**—As a rule, all glands, at some period in their development, are connected with the mucous surface by a tube called a duct. This connection, in most instances, persist, but where it disappears, the gland becomes isolated, and the term *ductless gland* is applied. Such are the adrenals, hypophysis and thyroid bodies, parathyroid, carotid and coccygeal glands, the ovary and the areas of Langerhans in the pancreas. These form an *internal secretion* that is absorbed by the circulatory or lymphatic system. Those with ducts pour their secretions or excretions into the various tracts with which they are connected.

CHAPTER IV.

CONNECTIVE TISSUES.

The **Connective Tissues** are the supportive tissues of the body. They are characterized by the predominance of the *intercellular substance* over the *cellular elements*. This intercellular substance varies in the different forms, as will be seen when each is considered. Connective tissues are usually vascular and are derived entirely from the mesoderm.

For the convenience of description, this class has been subdivided into the following varieties:

Fibrous.

1. WHITE.
   a. *Loose.*
   b. *Dense.*
2. YELLOW ELASTIC.
3. MUCOUS.
4. RETIFORM.
5. MIXED.

Modified.

6. ADIPOSE.
7. LYMPHOID.
8. CARTILAGE.
9. BONE.
10. DENTIN.
11. BLOOD.

The **Fibrous** varieties are characterized by the fibrous or semi-solid intercellular substance. The cellular elements are comparatively *few*, and are found scattered among the fibrils. There are several varieties of cells found in connective tissues. These are the TRUE, or FIXED, the WANDERING and the PLASMA cells. The TRUE, or FIXED, connective tissue cell is a flattened, stellate element with many processes that extend in all directions, and anastomose with those of other cells. These cells may be pigmented as

seen in the iris and choroid. Within the network thus formed lies the intercellular substance. In young tissue, the cells are not all of the above form. Some are round, others are spindle-shaped; these gradually become converted into the stellate variety.

The WANDERING cell passes into the tissue from the blood-vessels. It may return, or remain and become a fixed, or true connective tissue cell.

PLASMA cells are large, granular, fixed elements, especially noticeable in areolar tissue. They are at first oval or oblong, and later change to the stellate type.

The INTERCELLULAR substance is soft, and, in most varieties, fibrous. These fibrils react characteristically to certain stains, as will be pointed out later. They vary in thickness, and are arranged in bundles which may be parallel, or may interlace. These bundles lie in a more or less homogeneous *ground substance* that varies in quantity in the different varieties.

The *origin* of the intercellular substance is still in dispute. Two theories are advanced. According to some writers, it is of *intracellular origin*, while others claim it to be *intercellular* in derivation; in other words, it is formed in the homogeneous, semi-solid *intercellular* or *ground substance*, which exists before the fibrils appear. The real origin is probably by a combination of these two processes. It seems that the intercellular substance is formed from the peripheral protoplasm of the cell, which becomes fibrillar in character. This small amount of differentiated protoplasm is then supposed to increase itself, and so give rise to the remainder of the fibrils.

The origin of the elastic fibres is not so plain, both of the above views being held in regard to them. In elastic cartilage, they are of *intercellular* origin, but still the *intracellular* formation must not be lost sight of.

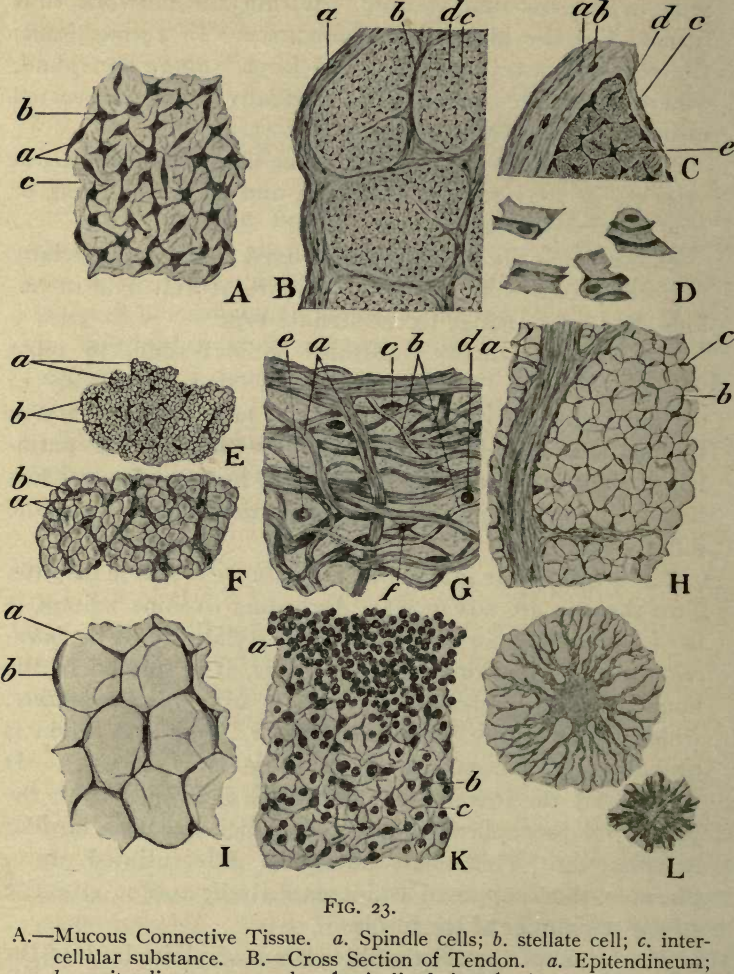

FIG. 23.

A.—Mucous Connective Tissue. *a*. Spindle cells; *b*. stellate cell; *c*. intercellular substance. B.—Cross Section of Tendon. *a*. Epitendineum; *b*. peritendineum; *c*. tendon fasciculi; *d*. interfascicular space. C.—Part of B, highly magnified. *a*. Epitendineum; *b*. cell in *a; c*. peritendineum; *d*. tendon fasciculus; *e*. interfascicular space. D.—Tendon Cells from Interfascicular Spaces. E.—Elastic Tissue, Cross-section of Ligamentum Nuchae. *a*. Elastic fibres; *b* white fibrous

1. WHITE FIBROUS tissue consists of fine or coarse bundles of inelastic fibrils, either parallel or forming a delicate meshwork. Its two subdivisions are, a, *loose*, and b, *dense*.

a. *Loose* fibrous connective tissue is a minute network of small bundles of fibrils formed for the support of capillary blood-vessels. The fibrils are delicate, less than 1 micron in diameter, do not branch or anastomose and are held in bundles by a small amount of cement substance. The cellular elements are of the types named above, and are few in number. Upon boiling, it yields gelatin, is not, or only slowly, digested by pancreatin, and is swollen by acetic acid.

It forms the capsules of organs, and is found as the tunica propria and submucosa of the alimentary and respiratory tracts.

b. In the *dense* variety, the fibrils are coarser, and arranged in larger bundles, which are usually parallel.

TENDONS are *dense* white fibrous tissues, in which all the fibril bundles have a *parallel* course. The whole structure is surrounded by a sheath of looser tissue, called the *epitendineum*, from the inner surface of which septa are sent in that divide the tendon fibres into large secondary bundles. These latter are further subdivided into primary bundles, each of which is surrounded by a minute sheath, the *peritendineum*. Between the individual bundles, lie the peculiar *tendon cells*. These are flattened, rectangular elements arranged end to end upon the tendon bundles.

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supportive tissue. F.—E highly magnified. *a*. Elastic fibres; *b*. white fibrous supportive tissue. G.—Areolar Tissue. *a*. White fibre bundles; *b*. elastic fibres; *c*. spindle cell; *d*. granule cell; *e*. plasma cell; *f*. stellate cell. H.—Adipose Tissue. *a*. Interlobular connective tissue; *b*. fat cells; *c*. nucleus and protoplasm and of the cell. I.—H highly magnified. *a*. Fat cell; *b*. protoplasm and nucleus of cell. K.—Lymphoid Tissue. *a*. Leukocytes; *b*. stellate connective tissue cells; *c*. reticulum. L.—Pigmented Connective Tissue Cell from a Pike.

The nuclei are peculiarly arranged. In two adjoining cells they will be seen near the line of junction, but in the cells on either side of these, they are separated by nearly the length of the two cells.

In FASCIA and the DURA the bundles are large, dense, interwoven and closely packed.

2. ELASTIC tissue, as its name indicates, has the peculiar property of *elasticity.*

The fibres are yellow in color, refractile, and coarser than those of the white variety, averaging 1–5 microns in diameter. In AREOLAR tissue, they are branched, while in other places bands and even membranes are formed (arteries). When separated and ruptured, the torn ends curl. This occurs in no other tissue. According to Mall, each fibre consists of a delicate sheath, surrounding the elastic substance; the latter stains deeply with magenta.

This variety occurs in the ligamentum nuchæ, where the fibres are very heavy, and are surrounded by white inelastic fibres, in the ligamentum subflava, in blood-vessels, and in the true skin.

Elastic tissue is digested by pancreatin and somewhat by pepsin, but not by acetic acid; upon boiling it yields *elastin.*

3. MUCOUS, or EMBRYONIC, connective tissue is that variety in which the intercellular substance is semi-fluid.

The *cellular elements* are mostly of the spindle-shaped variety, although numerous stellate cells are present. Round cells are also frequently seen.

The *intercellular substance* is semi-solid in the youngest tissue, and takes a peculiar homogeneous stain. As the tissue becomes older fibrils begin to develop, and of these, the white are formed into bundles, while the elastic are usually individual.

Mucous connective tissue is found in the umbilical cord,

in embryos, in the vitreous humor of the eye and in the pulp of the teeth.

4. RETIFORM connective tissues, or RETICULUM, is the supportive tissue of glands and gland-like organs. It consists of delicate bundles of fibrils forming a network, in the meshes of which are found the functionating cells of the organ. The cells are chiefly stellate in form, and their processes anastomose around the fibril bundles.

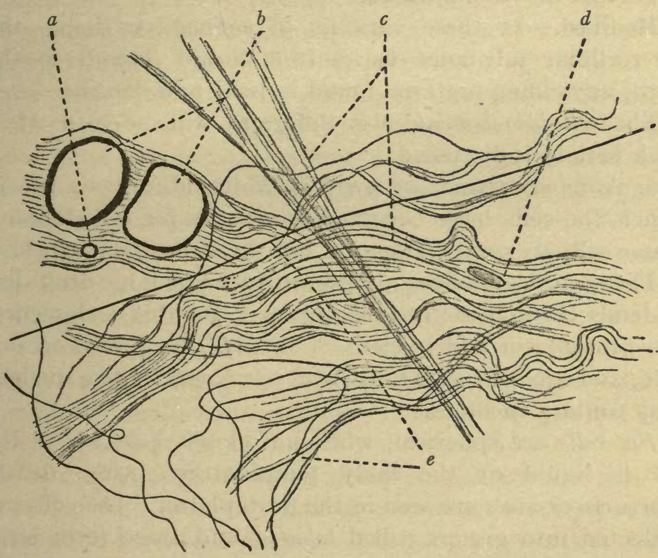


FIG. 24.—INTERMUSCULAR CONNECTIVE TISSUE BUNDLES OF MAN. *a*. Fat drop; *b*. fat cells; *c*. bundles of white fibres; *d*. nucleus of a cell; *e*. elastic fibres (*Stöhr's Histology*).

This tissue is more resistant to those reagents that dissolve the white variety (hydrochloric acid and potassium hydrate) and does not yield elastin upon boiling, but a mixture of gelatin and reticulin, nor is it digested by pancreatin.

5. MIXED, OR AREOLAR, connective tissue is a combination of the *white* and *elastic* varieties.

The *white* tissue is present in the form of delicate bundles, and these form a loose network with the *elastic* fibres, which are usually thin and branched. The *stellate* and *wandering* cells are well represented, but the plasma cells are more numerous than in any other variety of tissue.

This variety is found binding the skin to the fascia beneath and between muscles.

Modified.—In these varieties of connective tissue, the intercellular substance varies from liquid (blood) to the hard, unyielding material found in bone and dentin.

The *cellular elements* also differ, as will be seen when each variety is discussed.

6. ADIPOSE tissue, OR FAT, is white fibrous tissue, in which the cells have become repositories for fat globules. These cells are quite numerous, but the stellate shape is lost.

The minute globules unite to form a single large drop that distends the delicate cell-membrane. By this coalescence, the protoplasm and nucleus of the cell are forced to one side, and are seen as a thin *band*, or *crescent*. The nucleus may contain vacuoles.

Fat cells are spherical, when not closely packed, as the fat is liquid at the body temperature. After death, *margarin crystals* are seen in the protoplasm. The cells are collected into groups called *lobules*, and these form large masses called *lobes*. Blood-vessels, nerves and lymphatics are present in considerable number. The first named are especially numerous, as there is a close relation between fat deposition and the vascularity of the part.

According to some writers, *fat cells* are specialized connective cells that exist in no other form. This seems doubtful, however, as experiments have shown that when animals are starved, the *spherical*, fat-containing cells re-

turn to the *stellate* form as the fat is removed. From this, it would seem that these cells act merely as storage cells.

When adipose tissue is studied, after ordinary preparation, merely a network of fibres and cell boundaries is seen. This is due to the fact that the fat has been removed by the alcohol leaving the insoluble white fibrous supportive tissue. In such sections, the nucleated crescents of protoplasm are readily observable. In sections of *osmicated* fat, the peripheral cells are circular in outline, while the deeper ones are irregular and black, due to the action of the osmic acid, which is a characteristic reagent for fat. *Sudan III*, also used as a test for fat, stains the globules dark red.

Adipose tissue is found widely distributed over the body, except in the penis, scrotum, ear and eyelid. From the orbit and around the kidneys it never entirely disappears, though death be due to starvation.

7. LYMPHOID tissue is a special form of the connective variety consisting of a network of *reticulum*, in the meshes of which are found *leukocytes*, or *white blood-cells*.

These cells are usually the *small lymphocytes*, although varying numbers of the *large lymphocytes* (*hyalin cells*) *and polynuclear cells* are to be seen. For a description of these cells, see **Blood** (p. 107).

For readiness of comprehension, LYMPHOID tissue is divided into four varieties: a. DIFFUSE; b. SOLITARY FOLLICLE; c. PEYER'S PATCH, or AGMINATED FOLLICLE; and d. LYMPH NODE.

a. DIFFUSE LYMPHOID tissue is an indefinite collection of leukocytes in an organ. The cells are not especially arranged, neither is there a special supportive tissue present, as in the last two varieties.

It is found in the tunica propria of the alimentary and respiratory tracts, and the cells are merely scattered between the bundles of white fibrous tissue. It forms the

medulla of the thymus body, and the bulk of the tonsil and spleen, and is transient in character.

b. SOLITARY FOLLICLES are small, dense collections of leukocytes in white fibrous tissue, as above. There is no special supportive tissue present; although the outline may be slightly irregular, it is sharp. Each follicle usually shows a lighter center in which the cells are fewer and younger. This is called the *germinal center*, and here the new cells are formed by karyokinetic division.

Solitary follicles are found in the alimentary and respiratory tracts, the spleen and tonsil. They, like the diffuse variety, are transient structures. (See Fig. 41, page 115.)

c. A PEYER'S PATCH is a more or less regular collection of solitary follicles sharply outlined from the surrounding tissue. Each patch consists of ten to sixty solitary follicles, each of which usually shows a *germinal center*. (See Fig. 51, p. 141).

Peyer's patches are found in the ileum.

d. LYMPH NODES (Lymph Glands) are small, bean-shaped bodies interposed in the pathways of the lymphatic vessels. As they are closely related to the **Lymphatic System,** their structure will be there considered.

8. The CARTILAGES are characterized by a solid intercellular substance. The cellular elements also differ from those previously described.

Three varieties are found in man: the HYALIN, WHITE FIBRO and YELLOW ELASTIC.

The general structure will first be considered, under *perichondrium, cells and intercellular substance*.

The *perichondrium* is a fibrous sheath that surrounds cartilage and gives rise to its cellular elements.

It is composed of white fibrous tissue, and is divided, functionally, into two parts. This division is not apparent under the microscope, as the layers fade into each other.

The *outer* part is the *fibrous* layer, and contains few cells. The *inner portion*, or *chondrogenetic layer*, is rich in cells that are not of the stellate type, but flattened and elongated, or spindle-shaped. These are the *chondroblasts*, which become cartilage cells. Blood-vessels also are present.

The *cartilage cells*, or *chrondroblasts*, vary in the different portions of the cartilage. Just beneath the perichondrium, they are flat and thin, indicating an early stage. Toward the center, they gradually become broader until, finally, they are oval or round in form. Each cell is rich in protoplasm, which contains one or more vacuoles. The nucleus is usually prominent. The cell is sharply outlined from the surrounding substance by a thick wall, the *capsule*. This is a product of secretion of the cell, and it is cast off, as a rule, every time the cell divides. Each cell may be individual, or several may be seen within one capsule, which is due to the fact that the new cells did not form capsules for themselves. This is seen especially in ossification of cartilage. Between the cell and the capsule is usually a space called the *lacuna*.

The *intercellular substance* varies. In the HYALIN variety, it is apparently homogeneous; in *white fibro*, it is composed mainly of white fibrous tissue, while in the *yellow fibro* it consists of yellow elastic fibres.

HYALIN CARTILAGE is a peculiar bluish or pearly tissue, which is elastic, and readily cut with a knife.

The *cellular elements* are as above. They are quite numerous, and close together just beneath the perichondrium. Further down, a number are usually found within one lacuna and capsule.

The *intercellular substance* or *matrix*, is apparently homogeneous. Upon very careful study, and treatment with special reagents, it shows a fibrillar character, in the meshes of which is seen the *ground substance*, which is homogeneous.

This ground substance is formed by a fusion of the cast-off capsules, and responds very well to hematoxylin, showing a peculiar bluish color.

This variety of cartilage is found covering articular surfaces, lining joint-cavities, as the costal, tracheal and most

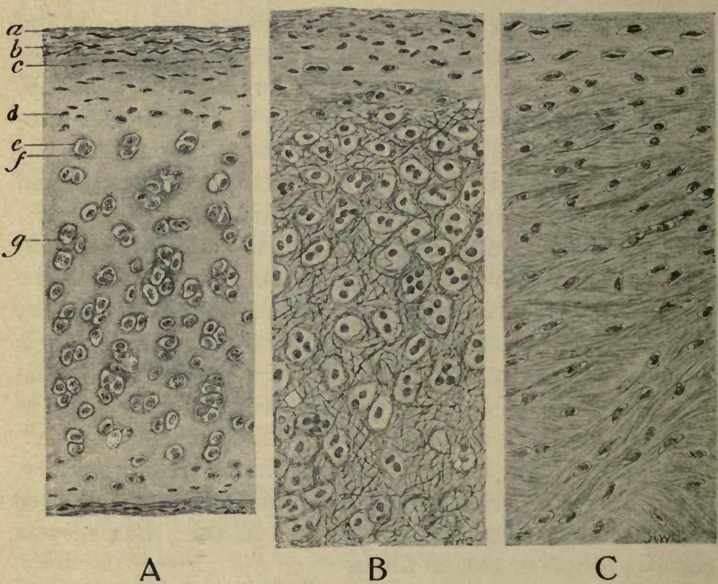


FIG. 25.—SECTIONS OF CARTILAGE.

A.—HYALIN CARTILAGE. *a.* Fibrous layer of perichondrium; *b.* genetic layer of perichondrium; *c.* youngest chondroblasts; *d.* older chondroblasts; *e.* capsule; *f.* cells; *g.* lacuna. B.—ELASTIC CARTILAGE. C.—WHITE FIBRO-CARTILAGE.

of the laryngeal cartilages. It precedes, with a few exceptions, all the bones of the body, and may ossify in old age.

WHITE FIBRO CARTILAGE consists of islands of the *hyalin* variety, separated by an *intercellular substance* made up of delicate bundles of *white fibrous tissue.* This form may calcify or ossify in old age.

It is not very abundant, and is found deepening joint-cavities, as inter-articular fibro-cartilages, and as the inter-vertebral discs.

YELLOW FIBRO, OR ELASTIC CARTILAGE is that variety in which the intercellular substance is composed of *elastic fibres*.

It is practically *hyalin* cartilage in which the hyalin matrix has been replaced by *elastic tissue*. The cartilage cells are found in small groups, surrounded by only a small amount of the hyalin substance. This variety never ossifies or calcifies, and is to be looked for in regions where elasticity is required, as in the epiglottis, ear, Eustachian tube and small laryngeal cartilages.

Cartilage contains no *blood-vessels*, except in the perichondrium, and during the developing stage. *Lymph channels* are said to be absent, so that its nutrition is not of a very high order.

9. BONE is the most highly differentiated of the connective tissues. It is characterized by the presence of a very hard, unyielding intercellular substance that has a characteristic arrangement.

BONES, like cartilage, are surrounded by a fibrous sheath, the *periosteum*, beneath which is the *bone substance* proper; the latter consists of *cells* and *intercellular substance*.

The *periosteum is composed of two layers—outer*, or *fibrous*, and *inner*, or *genetic*.

The outer layer consists of white fibrous tissue, supporting a large number of blood-vessels, and containing but few cells. The *inner*, or *genetic*, layer is rich in cells and capillaries. These cells are the *future osteoblasts* that secrete the osseous tissue. From its inner surface, it sends in bundles of fibres that pierce the layer of bone at right angles, and bind them together. These are *Sharpey's fibres*.

The *cells* are all of the irregular stellate type, and consist of flattened bodies and short processes that extend into small canals, to be described later. The protoplasm is not very abundant, and the nuclei are oval, and often vesicular.

The *intercellular substance* is hard and resistant. It consists of osseous material that is secreted by the cells, and is peculiarly arranged in the compact variety. It contains spaces, or *lacunæ*, from which extend minute canals, or *canaliculi*. Beside these, there are a great number of canals that vary in length and diameter. These are the *Haversian canals*.

BONE is composed of *inorganic* and *organic salts;* the *former* are soluble in mineral acids, by which they may be removed and the tissue cut. The *latter* are removed by burning, after which process the inorganic substance remains as a porous mold of the bone.

There are two varieties—CANCELLOUS, or SPONGY, and COMPACT, or SOLID.

CANCELLOUS BONE consists of *spicules* forming a network resembling a sponge. These *spicules* have a fibrillar structure, and contain little spaces, called *lacunæ*. In the living condition, these lacunæ are occupied by bone-making cells, termed *osteoblasts*.

This variety is found around the medullary cavity and in the heads of the long bones, and forming the central portion of the flat bones. The meshes of the network are covered by the *endosteum* and are filled with marrow.

COMPACT BONE has a characteristic structure. The osseous matter is arranged in layers, or *lamellæ*, between which lie the *lacunæ*. There are four varieties of lamellæ: a. *Periosteal*, *peripheral*, or *circumferential;* b. *Haversian*, or *concentric;* c. *Intermediate*, *ground*, or *irregular;* and d. *Perimedullary, or Internal.*

a. The *peripheral*, *periosteal*, or *external* lamellæ are

those formed directly from the periosteum. They are few in number, and several are required to complete the circumference. Between them are a number of irregular spaces, *lacunæ*, from which little canals extend, the *canaliculi.* The external layer has a number of small depressions called *Howship's foveæ*, or *lacunæ.* These are occupied by large bone-destroying cells called *osteoclasts.* Haversian

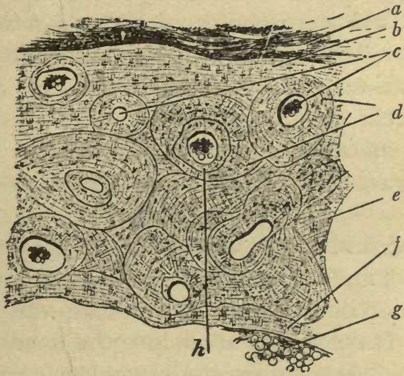


FIG. 26.—CROSS-SECTION OF HUMAN COMPACT BONE.
a. Periosteum; *b*. peripheral lamellæ; *c*. Haversian canals; *d*. lacunæ; *e*. interstitial lamellæ; *f*. perimedullary lamellæ; *g*. marrow; *h*. Haversian lamellæ (*Stöhr's Histology*).

canals are not present, but larger canals, containing blood-vessels from the periosteum, are seen. These are *Volkmann's canals.*

b. The *Haversian* lamellæ, which are probably the most numerous, are thin layers circularly arranged around a small central canal called the *Haversian canal.* These layers are separated by the lacunæ, and pierced by the canaliculi. The lamellæ of a system are parallel to one another, but the different systems usually run at various angles.

An *Haversian system* consists of the lamellæ, canal, lacunæ and canaliculi.

The *canals* are occupied by blood-vessels, nerves and lymphatics. Those nearest the marrow cavity contain marrow. The canals are generally parallel to the long axis of the bone, and anastomose freely with one another.

c. The *intermediate*, *interstitial*, or *irregular* lamellæ lie between the Haversian system, and are irregular in size and form. They are the remains of Haversian and periosteal lamellæ, altered by the growth of the bone in diameter. No canals are found here, but lacunæ and canaliculi are present between the lamellæ.

d. The *perimedullary*, or *internal*, lamellæ are not very regular, and are found surrounding the medullary, or marrow cavity.

The *lacunæ* are small, irregular spaces found between the various lamellæ throughout the bone, and occupy a portion of each of the adjacent lamellæ, and do not lie in one alone. These spaces are said to be lined by a delicate membrane. They contain the osteoblasts.

Extending in all directions, are small canals, or *canaliculi*, that communicate with those of other lacunæ, so that a series of intercommunicating spaces results. Those lacunæ lying nearest the Haversian canals, communicate with them, but the peripheral ones of a system do not communicate, to any great extent, with those of the interstitial lacunæ. The canaliculi serve as supports for the processes of the osteoblasts.

The compact portions of the heads of bones contain no Haversian systems and no large lacunæ so that pressure can more readily be borne. Vessels do not enter the bone here.

The MEDULLARY CAVITY, which contains the nutrient marrow, is a large space, in the shafts of the long bones; it

is lined by the *endosteum* which is analogous in structure and function to the periosteum.

The MARROW is of two varieties, *red* and *yellow*. The *red* is found in young persons, while the *yellow* occurs in those above the prime of life. The difference is due to the presence of a great deal of fat in the yellow, whereby the color becomes changed. It is not a blood-making tissue as the cellular elements are few or may be entirely wanting. In disease, however, it may again become red.

MARROW consists of a delicate network of reticulum, derived from the endosteum, supporting a close capillary plexus and a number of different *cells*. These cells are: MYELOCYTES, or MARROW CELLS; NUCLEATED RED BLOOD CELLS, or ERYTHROBLASTS, WHITE BLOOD CELLS, OR LEUKOCYTES, and MYELOPLAXES.

MYELOCYTES are large nucleated masses of granular protoplasm. The nucleus is usually large and oval or round in shape; the chromatin is small in quantity. The protoplasma contains fine granules that may or may not react to acid stains; pigment granules are not infrequently found. These cells may show ameboid movements, and are found in the blood in certain diseases.

ERYTHROBLASTS, or NUCLEATED RED CELLS.—These cells differ from the ordinary red cells in possessing a nucleus, and may show mitotic figures. They vary somewhat in size, but are seldom over 9.5 microns in diameter. By a loss of the nucleus, these cells become the *erythrocytes, or normal red cells*.

The LEUKOCYTES are usually the *finely* and *coarsely granular eosinophiles*, and the *basophiles; lymphocytes* are usually not numerous.

MYELOPLAXES, or OSTEOCLASTS, are very large, irregular cells. The protoplasm is abundant, and a number of nuclei may be seen. These cells are of great importance in bone

destruction, from which the term osteoclast is derived. They may be capable of ameboid movements and are phagocytic.

The functions of red marrow are to make erythrocytes, granular leukocytes in large numbers and to store fat.

Bones are nourished by *blood-vessels* that enter through the *nutrient foramen* and pass to the marrow cavity. From here, branches are sent to the various parts by way of the Haversian canals. Other vessels, derived from the periosteum, lie in Volkmann's canals, which are found in the circumferential lamellæ.

Nerves and lymphatics accompany the blood-vessels.

Development of Bone.—Bone is not a *primary*, but a *secondary* tissue. It is preceded by cartilage or by fibrous tissue. Bone developed from hyalin cartilage is called ENDOCHONDRAL, while that developed in fibrous tissue is referred to as INTRA-MEMBRANOUS bone.

ENDOCHONDRAL bone formation is the process by which the hyalin cartilage is converted into SPONGY bone. It is, in reality, a combined process, for so soon as the spongy bone is formed, this is changed to the *compact* variety by the *intra-membranous*, or *periosteal method*.

When OSSIFICATION begins, the cartilage cells in that vicinity begin to multiply rapidly, and arrange themselves in rows parallel with the long axis of the bone. Multiplication is most rapid in the center of the area, and, as a result, the new cells are unable to form new capsules for themselves; in consequence, a large number are seen in one space called a *primary areola*, or *marrow space*. In the cartilage between these spaces, calcareous matter is deposited, and the cells above and below arrange themselves into parallel rows. The cells within the areolæ either *disappear*, become *osteoblasts*, or *osteoclasts;* the latter dissolve the cartilaginous and calcareous partitions between the spaces.

As a result of the latter, larger spaces are formed, and these are the *secondary areolæ*. Those cells that become *osteoblasts*, lay down a thin layer of osseous tissue upon the remaining partitions, so that, at first, these consists of a core of calcific material covered by a thin veneer of true bone. As the process continues, the calcareous matter is entirely removed and is replaced by bone.

While these changes have been in progress, the *perichondrium* has become the *periosteum*, which now forms *osteoblasts*. These, with trabeculæ of the periosteum and blood-vessels, pass inward toward the center of ossification, and enter the areolæ. This *vascularization* forms the first marrow. The blood-vessels pass upward and downward from the center, following the process of calcification. Gradually, the delicate rod of cartilage is converted into a rod of spongy bone. The articular portions are separated from the shaft by an interposed disc, the *epiphyseal cartilage*.

Periosteal bone formation now begins. The *inner* surface of the periosteum becomes converted into a thin layer of osseous tissue, and the osteoblasts remain surrounded by a small space that is continued along its processes. This space and its continuations are the *lacunæ and canaliculi*. As the inner surface is changed to bone, the outer surface has a corresponding amount added to it, so that the thickness of the periosteum is proportionately the same.

With the formation of periosteal bone, the various *lamellæ* are formed. The *peripheral* are merely the converted periosteum. The *Haversian* system and *lamellæ* are formed in the following manner. From the inner surface of the periosteal layer, projections are formed at various angles. These meet other projections, thereby enclosing a small space, the *primitive Haversian canal*. *Osteoclasts* gain access and make this space regular and

larger. Then *osteoblasts* lay down layer upon layer of osseous matter until only a small channel, the *Haversian*

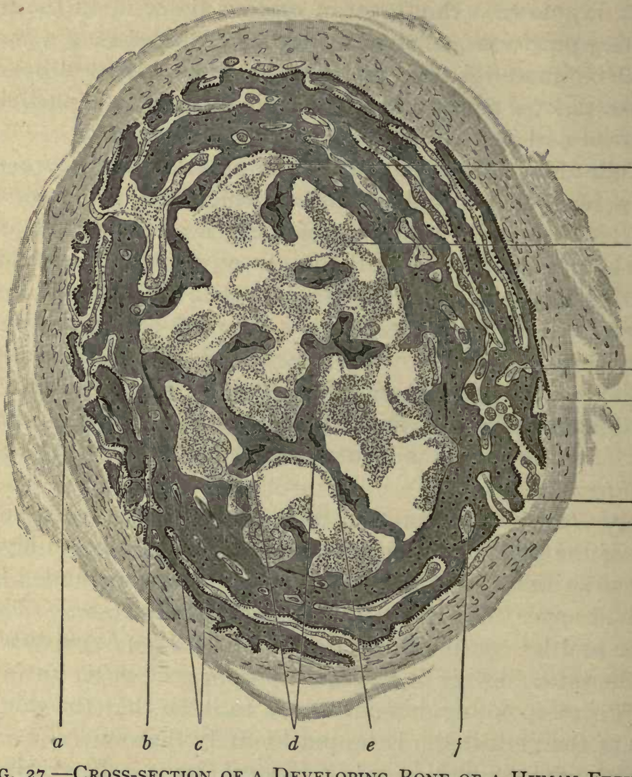


FIG. 27.—CROSS-SECTION OF A DEVELOPING BONE OF A HUMAN FETUS OF FOUR MONTHS.

a. Periosteum; *b.* boundary between endochondral and periosteal bone; *c.* perichondral bone; *d.* remains of area of calcification; *e.* endochondral bone; *f, f'.* blood-vessel; *g. g'.* developing Haversian spaces; *h.* marrow; *i.* blood-vessel (*Stöhr's Histology*).

canal, is left. The remains of the peripheral lamellæ between the various systems go to make up the *interstitial lamellæ.*

With the formation of the peripheral lamellæ, the network of spongy bone is removed from the center by *osteoclasts.* This leads to the formation of a *marrow cavity.* As the bone increases in size, the cavity increases in proportion, by the destruction of the surrounding bone. During the prime of life, *bone formation exceeds cavity formation*, but in old age, the *reverse* is the case, so that the shaft becomes thinner, and the cavity larger.

The bone *increases in diameter* by the continued addition of peripheral lamellæ, as a tree grows in thickness. It *grows in length* by the interposition of a disc of cartilage between the shaft and head of the bone. In this disc, new cartilage is formed as rapidly as ossification occurs. This is the *cambium layer*, and should it ossify, that end of the bone would no longer increase in length. This change occurs normally when full height is reached.

This method of bone formation occurs in all bones except those of the face and of the vault of the cranium.

Intra-membranous bone formation is the process whereby white fibrous tissue becomes converted directly into bone. Two periosteal layers are present, and between these, the bone is formed. Upon the fibrous bundles connecting them, osteoblasts deposit osseous material until all are converted at the same time the formation of Haversian systems occurs.

Such bones increase, in thickness, as above, and laterally, by the maintenance of a layer of fibrous tissue at their edges. This is the *cambium layer*, and when full growth is attained, this layer ossifies, and union occurs between the various bones.

10. Dentin will be considered under the teeth.

11. Blood is the *only liquid connective tissue.* As it is part of the circulatory system, it will be considered when that is described.

CHAPTER V.

MUSCLE TISSUES.

Muscle tissues are those which produce the various movements of the body, whether voluntary or involuntary. Like epithelial tissues, they consist chiefly of cellular elements, the intercellular substance being small in amount. The varieties are **voluntary striated, involuntary non-striated** and **involuntary striated.**

Voluntary striated muscles are characterized by being under the control of the will and are called skeletal muscles. Each MUSCLE consists of a large number of *units* called *fibres*, bound together by white fibrous tissue.

Each fibre, or *cell*, is a long, narrow cylinder. It varies from one to five inches in length, and exhibits *cross* and *longitudinal striations*. It is composed of a large number of *fibrillæ*, which are bound together by a membrane called *sarcolemma*, and separated from one another by *sarcoplasm*. Many peripherally located nuclei are present.

The *fibrillæ* consist of *sarcous elements* which stain darkly and are doubly refractile, or *anisotropic*. The *sarcoplasm* is a palely staining, semi-solid substance that lies between the fibrillæ, and is slightly refractile, or *isotropic*.

The *longitudinal striations* are formed by the alteration of the fibrillæ and the sarcoplasm, and are usually not as distinct as the cross, though at times the reverse is the case. The *cross striations* are due to the alternation of *light* and *dark discs*, or *bands*. The *dark bands*, or *Bruecker's lines*, are composed of rows of parallel *sarcous elements*, separated by the sarcoplasm. These *sarcous elements* are cylindric except at the ends, where they are cone-shaped. The

ends form part of the light disc. Each dim band is divided transversely by a less refractile line, called *Hensen's disc.*

The *light discs* are subdivided into three portions, an *intermediate* and *two lateral.* The *intermediate disc* consists of a single row of small globules, interposed between the apices of the cones. These are *Dobie's globules*, or the *membrane of Krause.* The *lateral disc* are merely the cone-shaped continuations of the sarcous elements. They are a little dimmer than the intermediate disc. It will be seen from the figure that the main portion of this light disc consists of the refractile sarcoplasm.

The *nuclei* are numerous, and are found beneath the sarcolemma, but external to the muscle substance. They are long and rather narrow, but respond well to the stain. In some animals the nuclei lie in depressions in the fibres.

The SARCOLEMMA is a delicate fibrous sheath that lies close to the fibre. It is not seen, as a rule, except by special preparation. If a fresh muscle fibre be treated with water, the muscle substance ruptures, and the delicate membrane is shown spanning the interval.

Upon cross-section, the fibres show a sharp outline, and the peripheral nuclei are readily distinguished. Upon careful observation, the fibrillæ are seen collected into groups, constituting *Cohnheim's fields.*

There are two kinds of fibres, white and red. The white predominate in man and are poor in sarcoplasm. The red are rich in sarcoplasm and the nuclei are deeply placed. The red is intermediate between myoplasm and the white fibres, and in some animals (rabbit) they form whole muscles. The trapezius muscle of man contains both red and white fibres.

Contractility is an inherent quality of the sarcous elements, but the sarcoplasm does not possess it. Occasionally, among the tongue muscles are found some fibres that branch. Such fibres are numerous in the tongue of the frog.

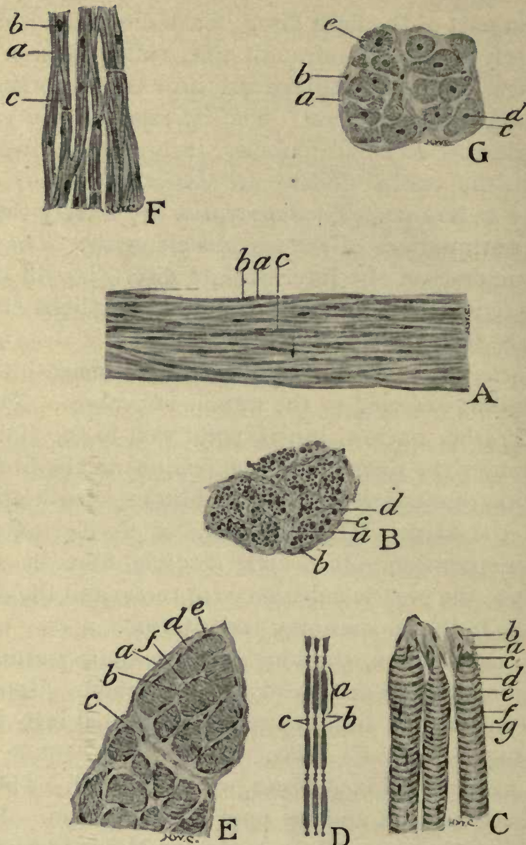


FIG. 28.

A.—Longitudinal section of smooth muscle fibres—*a*. muscle fibre; *b*. nucleus; *c*. fibrous tissue between fibres. B.—Cross-section of smooth muscle fibres—*a*. perimysial connective tissue; *b*. blood-vessel; *c*. nucleated fibre; *d*. nonnucleated fibre. C.—Longitudinal section of voluntary muscle fibres.—*a*. sarcolemma; *b*. nucleus; *c*. end of muscle fibre; *d*. dark bands; *e*. intermediate disc; *f*. nucleus; *g*. lateral disc. D.—Diagrammatic section of cross and long striations—*a*. dark disc; *b*. lateral discs; *c*. intermediate disc. E.—Cross section of voluntary muscle—*a*. perimysium; *b*. endomysium; *c*. nucleus of perimysium; *d*. fibrillæ; *e*. nucleus of muscle; *f*. sarcolemma. F.—Longitudinal section of cardiac muscle fibres—*a*. muscle fibre; *b*. nucleus; *c*. branch. G.—Cross section of cardiac muscle fibres—*a*. perimysial sheath; *b*. nucleus of sheath; *c*. muscle fibre; *d*. nucleus; *e*. radial plates of fibrillæ.

Muscles.—Fibres are collected into definite groups called **Muscles.** Each muscle is surrounded by a sheath of white fibrous tissue called the EPIMYSIUM. From its inner surface, septa are sent in that divide the muscle into a number of large *secondary bundles.* These secondary bundles are further subdivided into *primary bundles,* or *fasciculi,* which are invested by a sheath, the PERIMYSIUM. This sends in fibres that pass between the individual fibres, and these represent the ENDOMYSIUM. Where the muscle joins the tendon, the nuclei are especially numerous.

The *blood-vessels* pierce the epimysium and form branches that follow the larger septa and ultimately reach the perimysium, where smaller branches are formed. These pierce the perimysium, and form longitudinal capillary meshes, which anastomose and at intervals show peculiar dilatations.

Lymphatics are usually not numerous, and may even be wanting.

The *nerves* follow the blood-vessels, but the exact method of termination will be considered under **Nerve Endings.**

Voluntary striated muscles are found as the skeletal and external ocular muscles, in the tongue, pharynx, upper part of the esophagus, anus, diaphragm, and in the external ear and larynx.

The **Involuntary Nonstriated, Smooth,** or **Visceral** muscle is not under the control of the will.

The individual fibres are short, narrow and spindle-shaped. Each is surrounded by a delicate sheath which, however, is not a sarcolemma.

Longitudinal striations are usually found, and these are due to the presence of coarse fibrillæ at the periphery of the fiber.

In each fibre there is but *one nucleus,* which is long, slender, darkly staining and centrally located. This is not

seen in all cross-sections, but when present, shows as a small, dark dot. *Branched fibres* have been found in the aorta and bladder muscle.

These fibres vary in length from 25 to 200 microns, ordinarily, but in the gravid uterus may attain a length of 600 microns. In diameter, they average about 5 to 7 microns.

The fibres are arranged in bundles like the above, but instead of forming masses like muscles, the bundles are arranged into layers, which extend circularly and longitudinally, in the hollow viscera.

Capillaries exist between the fibres as above.

The *nerves* are chiefly of the *sympathetic* variety.

Nonstriated muscles are found in the alimentary tract from the middle third of the esophagus to the anus, in the ducts of glands, in the trachea and bronchial tubes, within the eyeball, the internal urinary and genital systems ,circulatory (except the heart) and lymphatic systems, and the capsules of some organs.

Involuntary Striated, Cardiac, or **Branched Muscle** is that variety found in the heart.

The *fibres* are short, stubby cylinders, possessing striations but no *sarcolemma*, although a delicate investing sheath is present. These fibres vary from 100 to 200 microns in length, and 25 to 40 microns in breadth.

A single large, oval, centrally placed nucleus is also present; this is usually surrounded by a zone of peculiar, undifferentiated protoplasm, in which pigment granules may be found. These pigment granules are numerous and constant in certain diseases of the heart muscle. Sometimes there are two nuclei.

The *transverse striations* are usually fainter than the longitudinal.

A peculiarity of this variety is that the fibres *branch*. These branches are short and narrower than the cell-body,

and anastomose with the branches of other cells, thus forming a *syncytium*.

In cross-sections, the fibrillæ are seen to be particularly arranged. They are formed into *radial plates* that start from the center or the zone of undifferentiated protoplasm that surrounds the nucleus.

The *blood-vessels* enter into intimate relation with the fibres, and are derived from the coronary arteries, the smaller branches of which lie between the muscle bundles. The capillaries pass into these and run parallel to the fibres, in which they often lie in grooves, and are frequently seen *within the fibre*, surrounded by the muscle substance.

The *nerves* are *both sympathetic* and *cerebrospinal*. *Sympathetic ganglia* are also present.

The following table will give the various characteristics of the muscle tissues in comparison.

CHARACTERISTIC.	VOLUNTARY STRIATED.	SMOOTH.	CARDIAC.
Shape.	Long cylinder.	Spindle.	Stubby cylinder.
Length.	1–5 inches.	25–200 microns.	100–200 microns.
Nucleus.			
Number.	Many.	One.	One.
Location.	Peripheral.	Central.	Central.
Shape.	Intermediate.	Rod.	Oval.
Striations.	Cross and long.	(Longitudinal occasionally.)	Cross and long.
Sarcolemma.	Present.	None.	None.
Branches.	Occasional.	(Occasional.)	Always.
Arrangement.	In masses called muscles.	In layers.	As a syncytium.
Control.	By will.	Not by will.	Not by will.

CHAPTER VI.

NERVE TISSUES.

The **Nerve Tissues** are the most highly differentiated of all the tissues.

There are two varieties, **gray** and **white.** The **gray** is characterized by a grayish color, and, in the central nerve system, is divided into layers. In the spinal cord and ganglia, its arrangement is different. It consists of CELLS and their processes and INTERCELLULAR SUBSTANCE, the latter which is called the NEUROGLIA, or SUPPORTIVE SUBSTANCE; myelinated and amyelinated nerve fibres are also present.

A *typic* nerve cell consists of a *cell-body*, from which a number of *processes* extend, a *nucleus* and *nucleolus*. The whole structure is also called a *neuron*.

The *cell-body* consists of granular and fibrillar protoplasm, which at the point of origin of the main process is formed into a mass, the *axis cylinder hillock*. The fibrillæ are called neurofibrils, are seen only after careful preparation according to Golgi's method, and require a high magnification. Some fibrillæ seem to be connected with the cells, while others apparently pass right through the cell-body. Besides the usual granules some very large darkly staining bodies are seen in the vicinity of the nucleus. These are the *corpuscles of Nissl*, or the *tigroid bodies*. The *nucleus* is usually large and vesicular while the *nucleolus*, also large, stains very darkly and is quite prominent. Cells vary from 5 to 130 microns in diameter.

The *processes* are of two varieties, *axis cylinder* and *den-*

dritic. The *axis cylinder*, *neurit*, or *axone*, is the main and largest process. It forms the means of communication between the cells of an area or those in different regions. It arises at the *hillock* and consists of fibrillated protoplasm. There is usually but one to each cell, but some cells with two and more axones have been found. Axones give off branches, at right angle, called collaterals, except the cells of the spinal ganglia. These may or may not be myelinated. How these processes terminate will be considered later.

The *dendrites* are the delicate secondary processes of a nerve cell. The number of these processes, in reality, gives us the basis of the classification according to structure. As they leave the cell-body they dwindle rapidly in diameter; this is due to their prolific branching. These smaller divisions are the teledendrites and serve to bring the cell-body in physiologic relation with other cells. These processes are usually amyelinic and do not leave the gray substance. In the case of the cells of the ganglia of the spinal, cranial and special sense nerves (sensor cells), the peripheral process, called usually a nerve fibre, is in reality the *myelinated dendritic process*. The *axone* grows into the central system from the ganglion.

Nerve cells are classified as to 1, **Structure**, 2, **Type.**

There are three varieties of cells according to **Structure,** or number of processes: UNIPOLAR, BIPOLAR and MULTIPOLAR.

The UNIPOLAR CELLS are those possessing but *one process*. In the early embryonal condition two were in reality present but the growth of the cell was such that the two were thrown together as one. The individuality of each portion, however, is retained. These cells occur in the spinal ganglia.

The BIPOLAR CELLS are those having *two processes*. The *dendritic process* very rapidly breaks up into a great number

of smaller ones called *telodendrites*. This variety is found in the cerebellum and peripheral sensor system (special senses).

The MULTIPOLAR CELLS which are the most numerous, have *three*, or *more*, *processes*. They are found in the cerebrum, cerebellum and spinal cord.

Types.—There are *two types* of cells according to the course of the axis cylinder. In CELLS OF THE FIRST TYPE (DEITER'S CELLS) the axis cylinder *leaves* the gray substance to become a *myelinated nerve fibre*. In the SECOND TYPE (GOLGI'S CELLS) the axis cylinder *never* leaves the gray substance.

The NEUROGLIA is the distinctive supportive structure of the nerve system. It is *not connective tissue*. Unlike the intercellular substances elsewhere, it is *not the result of the secretion of the functionating cells* (nerve cells) but is formed by special cells called *neuroglia*, or *glia cells*. These cells secrete the intercellular substance of the neuroglia.

The *glia cells*, or *astrocytes*, are of two varieties, *spider* and *mossy*.

The *spider cells* possess small bodies which send out many thick branches varying in length. They are found in the white substance and their processes interlace to form a supportive network for the nerve fibres. They are the more numerous.

Mossy cells possess larger cell-bodies but shorter processes that are finer and more branched. They occur chiefly in the gray substance.

In addition to the above a small amount of connective tissue is found in the gray substance. This penetrates with the blood-vessels.

The gray substance is found in the cerebrum, cerebellum, pons, oblongata, spinal cord and ganglia.

The **White substance** consists of myelinated nerve fibres

bound together by neuroglia and connective tissue, the latter of which supports the blood-vessels chiefly.

Nerve Fibres, the continuations of cells of the first type, are of two varieties, **Myelinated** and **Amyelinated.**

Myelinated, or **Medullated**, nerve fibres have a characteristic structure. Each consists of an AXIS CYLINDER that lies in the center and represents the cell and shows a fibrillated structure somewhat like that of a muscle fibre. The fibrillæ are separated by a pale, homogeneous substance that does not respond to ordinary stains and is called the *neuroplasm*. This axis cylinder is surrounded by a delicate membrane, the *axilemma*.

The MYELIN OF MEDULLARY SHEATH, OF WHITE SUBSTANCE of SCHWANN, surrounds the axis cylinder. It consists of a fine network of *kerato-hyalin* containing in its meshes a fatty substance, the *myelin*. The latter is blackened by osmic acid.

The NEURILEMMA, OF SHEATH OF SCHWANN, is a tender covering that enfolds the individual nerve fibre. Not all myelinated nerve fibres possess neurilemmæ, as the fibres of the optic and olfactory nerves, of the spinal cord and brain mass are devoid of this sheath.

At regular intervals are annular constrictions, where the neurilemma dips and touches the axis cylinder. These places are the *nodes of Ranvier*, and at such points the axis cylinder may give off branches called *collaterals*. The portion between the nodes is an *internode;* each contains a nucleus. In the internodes, *funnel-shaped depressions*, the *clefts of Lantermann*, are seen.

Nerve fibres are *motor* or *centrifugal* or *efferent* on the one hand and *sensor*, *centripetal*, or *afferent* on the other. Those *sensor* fibres found peripheral to the ganglia are in reality myelinated *dendrites* and not *axones*, as is usually stated. They vary from 2 to 20 microns in diameter.

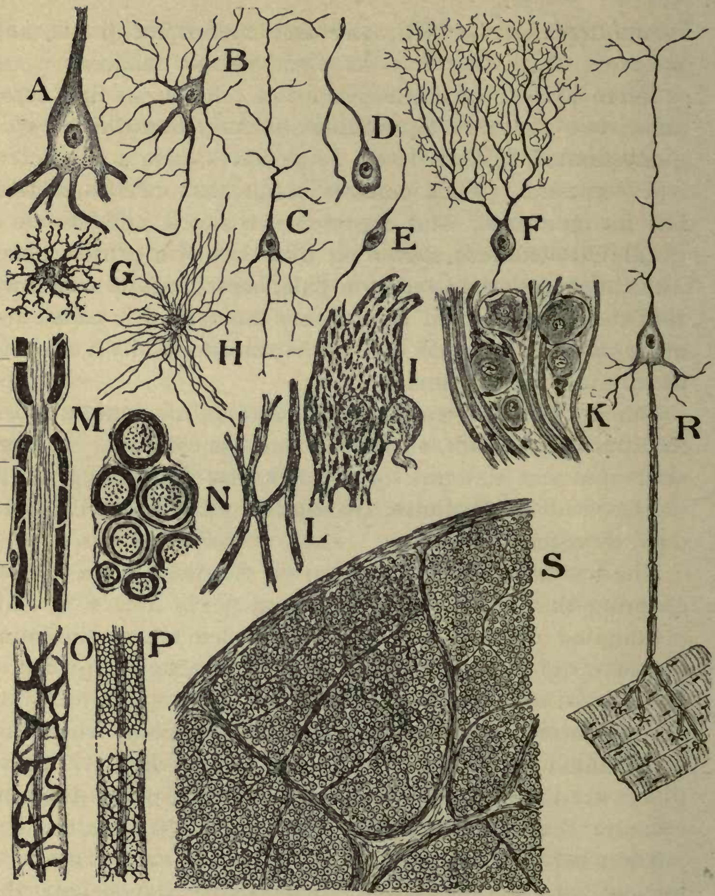


FIG. 29.

A. Multipolar cell from cerebral cortex; B. multipolar cell from spinal cord; C. pyramidal cell from cerebral cortex; D. unipolar cell; E. bipolar cell; F. cell of Purkinje, antler cell; G. mossy cell; H. spider cell; I. cell from spinal cord of an ox, showing pigment granules; K. ganglion; L. sympathetic or amyelinated fibres; M. longitudinal section of myelinated nerve fibre—*a*. neurilemma; *b*. myelin sheath; *c*. axis cylinder; *d*. node of Ranvier; *e*. nucleus; N. cross-section of osmicated nerve fibres; O.-myelinated nerve fibre of a guinea-pig showing the reticulum; P. myelinated nerve fibres of a toad, showing reticulum (kerato-hyalin); R. motor neuron, showing nerve cell, dendrites, axis cylinder and ending of latter in a muscle; S. cross-section of nerve trunk.

An **Amyelinated,** or **Nonmedullated,** nerve fibre is one that possesses *no myelin sheath.* It is merely a naked axis cylinder surrounded by its axilemma. All the sympathetic fibres are of this variety but some are found in the cerebro-spinal system.

A **Nerve** is a collection of nerve fibres arranged in a definite manner.

Each **Nerve** is surrounded by a sheath of white fibrous tissue, the EPINEURIUM. From this, septa pass inward and divide the nerve into large *secondary bundles* that are further subdivided into *primary bundles,* or *fasciculi,* each of which is surrounded by the PERINEURIUM. The fibres contained in the fasciculi are separated from one another by the ENDONEURIUM, which is a continuation of the perineurium.

The *blood-vessels* pierce the epineurium and branches are sent along the septa into the primary bundles. Here capillaries are formed, which run parallel to the fibres. These vessels are the vasa nervorum.

Ganglia are collections of gray substance and are found in the cerebrum, as the *basal ganglia;* in the sympathetic system, as the *sympathetic* ganglia; and, within the intervertebral foramina, as the *spinal ganglia.*

A **Ganglion** consists of a limiting sheath, or CAPSULE of white fibrous tissue within which the nerve, or **ganglion cells** are found.

The **ganglion cell** is a large spherical element surrounded by a distinct space (lymph space) lined by endothelial cells, and consists of granular protoplasm containing a large, palely staining nucleus, and a distinct nucleolus. It is usually of the *unipolar* variety. Between these cells are seen *myelinated* and *amyelinated* nerve fibres, and connective tissue containing blood-vessels and lymphatics.

Nerve Organs are of two varieties, 1, **Sensor,** or **Nerve**

Beginnings, and **Motor,** or **Nerve Endings,** considering them from a physiologic or functional standpoint.

The **Sensor Organs** are FREE, TACTILE CELLS and CORPUSCLES.

FREE BEGINNINGS are found in mucous membranes, especially in stratified epithelium. The nerve fibres apparently reach the basement membrane, and upon piercing this lose the neurilemma and myelin sheath. These branches then divide repeatedly between the epithelial cells.

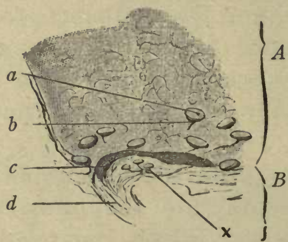


FIG. 30.—VERTICAL SECTION OF SKIN OF GREAT TOE OF A MAN.
A. Epidermis; B. derma; *a*. tactile cell; *b*. tactile meniscus; *c*. nerve fibre; *d*. connective tissue sheath of same; *x*. tactile cells in derma (*Stöhr's Histology*).

TACTILE CELLS are *simple* and *compound*.

The *simple* variety consists of a *disc-like* structure, 6 to 12 microns in size, which lies within the epithelial layer. From this disc, or meniscus, passes a naked axis cylinder, and upon the *disc* lies the *tactile cell* which is a mass of granular protoplasm.

Compound tactile cells consist of two or more *discs* containing between them the *tactile cells*. A branch of a myelinated nerve fibre passes from each cell. These structures are usually 15 by 30 microns in size.

Tactile Corpuscles, or **Bulbs** are the most differentiated of these organs. They vary in complexity from the com-

paratively simple GENITAL and CONJUNCTIVAL CORPUSCLES to the CORPUSCLES OF MEISSNER AND VATER.

The GENITAL and CONJUNCTIVAL CORPUSCLES are spherical bodies in which the cells are not regularly arranged. The nerve fibres begin probably between the cells. These organs average from 60 to 400 microns in length and may have as many as ten nerve fibres connected with one.

The CORPUSCLE OF MEISSNER is a complex structure in which the individual cells cannot be distinctly seen. It is

FIG. 31.—CORPUSCLE OF MEISSNER FROM GREAT TOE OF MAN. *n*. Myelinated nerve fibre; *h*. connective tissue sheath; *e*. varicosities. The nuclei are invisible (*Stöhr's Histology*).

surrounded by a sheath that encloses a number of transversely placed nuclei. One or more nerve fibres is connected with each corpuscle, and upon contact with the corpuscle the neurilemma is lost. The myelin sheath soon follows and the axis cylinders, after a spiral course are thought to connect with the end discs or *menisci*. These bodies measure 35 to 50 microns by 45 to 100 and are found in the papillæ of the palmar and plantar surfaces of the true skin.

CORPUSCLES OF VATER, or PACINIAN BODIES have a very definite structure. Each consists of a CAPSULE, INNER BULB and KNOB. The CAPSULE consists of lamellæ, of con-

nective tissue concentrically arranged, which are usually bound together by an *intracapsular ligament.* The layers are covered by endothelial cells and represent so many lymph spaces.

The INNER BULB is an elongated cylindric mass of granular protoplasm that is connected with the axis cylinder of the nerve.

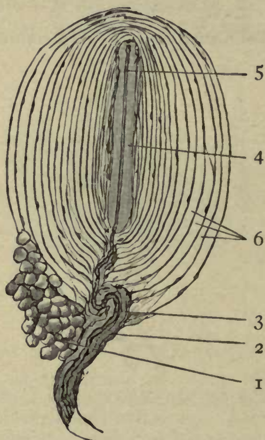


FIG. 32.—PACINIAN BODY FROM MESENTERY OF A CAT.
1. Fat cells; 2. artery; 3. nerve fibre; 4. inner bulb; 5. axis cylinder; 6. layers of the capsule (*Stöhr's Histology*).

As the nerve meets the capsule the neurilemma is lost. When it reaches the inner bulb the myelin sheath disappears and the naked dendrite continues through the inner bulb and ends in a *club-like mass*, the KNOB.

These corpuscles occur in the derma, near joints, in the mesentery (especially in lower animals) and along tendons.

Neuromuscular Organs.—These organs are spindle-shaped, and consist of 4 to 20 small voluntary muscle fibres, the *intra-fusal fibres*, surrounded by a delicate white

fibrous sheath, the *axial sheath*. External to this is the capsule composed of about six layers of white fibrous connective tissue concentrically arranged and separated from the axial sheath by a lymph space.

In the equatorial region of the organ the muscle fibres consist chiefly of sarcoplasm and the striations are faint, while at the ends the striations are quite distinct.

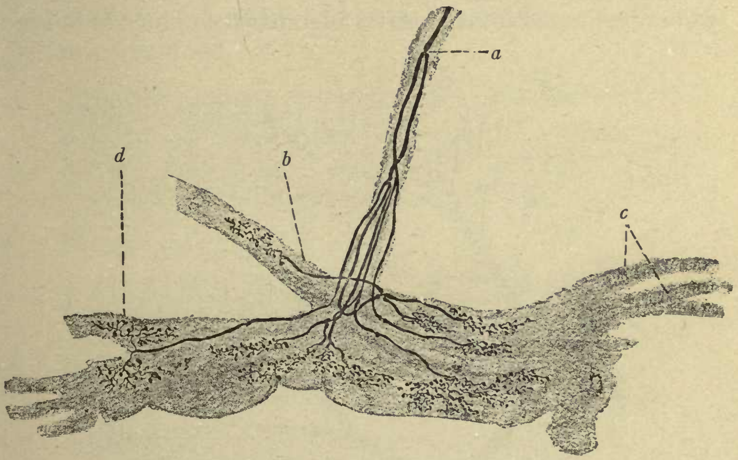


FIG. 33.—TENDON-SPINDLE OF A CAT.

a. Myelinated nerve fibre; *b*. tendon bundle; *c*. muscle fibres; *d*. terminal ramifications (*Stöhr's Histology*).

Each fibre arises as a small bulb-like knob and then winds around the intrafusal muscle fibres. As the axial sheaths are reached each branch becomes myelinated. The various fibres, representing myelinated dendrites, join and leave the capsule of the organ as one or more fibres.

These organs are readily visible to the naked eye, measuring 1 mm. to 4 mm. by .1 mm. to .2 mm. They are found

in greater numbers in the small muscles of the hand and foot.

The **neurotendinous** beginnings resemble the above in structure, with the exception that the intrafusal fibres are tendon bundles and the amyelinated fibres do not wind around the intrafusal fibres, but have short branches that arise in little plates upon the tendon bundles.

The **Motor** endings of the voluntary muscles are chiefly from myelinated fibres. After piercing the epimysium, the

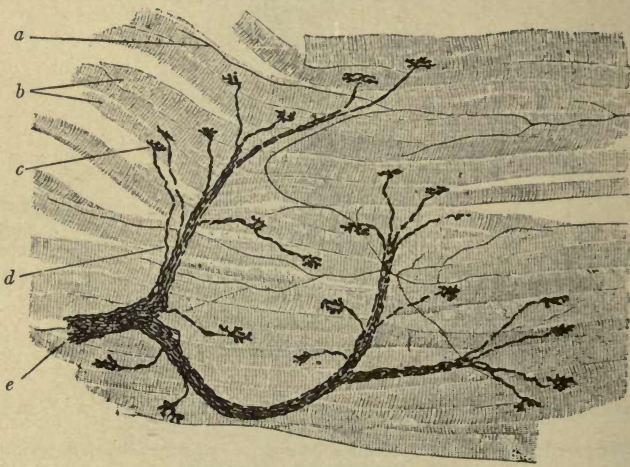


FIG. 34.—MOTOR NERVE-ENDINGS IN INTERCOSTAL MUSCLE OF A RABBIT *a.* Sensor nerve fibre; *b.* muscle fibres; *c.* motor plates; *d.* myelinated nerve fibre; *e.* bundle of nerve fibres (*Stöhr's Histology*).

nerve follows the septa to the primary bundles and breaks up into fibres of which each muscle fibre receives one; no doubt one nerve fibre supplies many muscle fibres. The neurilemma and myelin sheath of the nerve fibres, upon passing through the sarcolemma blend with it, and the axis cylinder breaks into fibrillæ each of which forms a number

of bulbous enlargements that pass to a *sole-plate*. This sole-plate consists of a mass of nucleated, granular protoplasm and with the bulbous nerve masses constitutes the *end-plate*.

The cardiac and involuntary nonstriated muscles are supplied by the sympathetic system. These nerve fibres form *plexuses* of delicate fibres at the intersections of which are found ganglia of various sizes. Individual branches extend to the muscle fibres, but the exact manner of ending is not understood.

CHAPTER VII.

CIRCULATORY SYSTEM.

The **Circulatory System** comprises the **Heart, Arteries, Capillaries, Veins** and the circulating fluid, the **Blood.**

THE HEART.

The **Heart** is the most important member, as on its contractions depends the circulation. It is a thick muscular organ composed of three coats, the ENDOCARDIUM, MYOCARDIUM and EPICARDIUM.

The ENDOCARDIUM consists of a lining of *endothelial cells* which rest upon the *subendothelial* (fibro-elastic) *tissue.*

The *endothelial cells* are flattened, nucleated plates that have an irregular outline and are held together by a small amount of intercellular cement. They differ but slightly from those found within the vessels.

The *subendothelial tissue* consists of a network of white fibrous and yellow elastic tissues. It may contain a few involuntary nonstriated muscle fibres. Here also are seen some partly developed heart muscle fibres, called Purkinje fibres; the fibrillæ are few and form a peripheral ring. They are common in some mammalian hearts, and in man they are represented by the terminals of the **Bundle of His.**

Guarding the auriculo-ventricular orifices and the openings into the pulmonary artery and aorta are duplications of the endocardium called VALVES. Around the openings the fibro-elastic tissue is condensed to form a ring-like mass, the ANNULI FIBROSI. These rings serve as origins for the valves.

The VALVES consist of two layers of endothelial cells, continuous at the edges, separated by the subendothelial tissue in which the inelastic tissue predominates. The auricular muscle may extend for a short distance into the auriculo-ventricular valves. The *chordæ tendineæ* consist of cords of fibrous tissue surrounded by endothelial cells. Above they are attached to the valves and below to the papillary muscles. The SEMILUNAR VALVES possess a marginal band with a central enlargement, the *corpus Arantii*. Upon each side of the corpus is a small semilunar fold called the *lunula*. The band strengthens while the corpus and lunulæ ensure complete closure of the valves.

The **Atrioventricular Bundle,** or **Bundle of His,** consists of a bundle of peculiar fibres that connect auricles and ventricles. It arises near the orifice of the coronary sinus, passing forward between the annulus ovalis and the auriculo-ventricular septum and turns down into the auriculoventricular septum at the base of the median leaflet of the tricuspid valve; it passes into the *pars membranacea*, and at the beginning of the muscular portion of the interventricular septum it divides into two fasciculi, one for each ventricle. These bundles lie just beneath the endocardium, surrounded and insulated by fibrous connective-tissue sheaths. Passing toward the apex of the heart each bundle upon reaching the lower third sends branches to the papillary muscles and there forms a large number of twigs that extend in all directions over the ventricular surface and come into histologic relation with the cardiac muscle fibres.

The muscle fibres are striated but the sarcoplasm predominates. The fibrillæ are few and peripherally placed, forming a circle or irregular or triangular groups. The volume and size is greater than in the ordinary cardiac fibres. The pigmentation is localized and not prominent. The cell-boundaries cannot be definitely located so that these cells

form a *syncytium*. These fibres represent early stages of muscle development from undifferentiated protoplasm.

The MYOCARDIUM consists of involuntary striated muscle. In the auricles the fibres are arranged in two layers, *inner longitudinal* and *outer circular*. In the ventricles the fibres cannot be separated so distinctly into layers. Some run longitudinally, other transversely, while the greatest number have an oblique, circular, or spiral course, forming even a figure eight. Owing to this arrangement distinct lamellæ cannot be formed. Usually incomplete *internal* and *external longitudinal* layers are formed between which are seen the *circular* fibres that form the thickest layer. Besides the latter are found spiral and oblique fibres that are present chiefly in the upper and lower portions of the left ventricle.

The EPICARDIUM, OR VISCERAL LAYER OF THE PERICARDIUM, consists of two portions, *serous*, and *fibrous*. The *serous* part is practically a duplication of the endocardium in structure. It consists of *endothelial cells* and *subendothelial tissue*. It differs from the endocardium, however, in being separated, usually, from the myocardium by a thin layer of adipose tissue and in possessing no muscle fibres. It continues up over the great vessels for a short distance and is then reflected over a thick sac of fascia, which constitutes the *fibrous* portion. This part is continuous, above, with the fascia of the neck, and below is attached to the diaphragm.

The *blood-vessels* are branches of the coronary arteries, and their relation to the muscle fibres has been described under **Muscle Tissues.** The endocardium is nourished by the blood that flows over it.

Lymphatics are present in all the coats but do not communicate with one another to any great extent.

The *nerves* are from both systems. Sympathetic ganglia are numerous.

The blood is sent from and returned to the heart by the **Vessels.** Of these there are three varieties, 1, **Arteries,** or **Efferent** vessels; 2, **Capillaries,** or **Connecting** vessels; 3, **Veins,** or **Afferent** vessels.

1. For convenience of description, the **Efferent** vessels (**Arteries**) are classed as LARGE, MEDIUM and SMALL. The LARGE are the AORTA and PULMONARY ARTERY; the MEDIUM the remainder of the named arteries of the body, and the SMALL, the unnamed branches that gradually become capillaries. All have the same general structure, consisting of three coats, TUNICAS INTIMA, MEDIA and ADVENTITIA; they carry the blood from the heart.

As the medium-sized artery is the type, its description will be considered first and then the differences between it and the others will be pointed out.

MEDIUM-SIZED ARTERY. The TUNICA INTIMA, or INTERNA, consists of three layers, the *endothelial*, *subendothelial* and an *internal elastic lamina*.

The *endothelial cells* differ but little from those lining the heart. They rest upon the *subendothelial fibro-elastic tissue*. Limiting this coat externally is a prominent wavy band of elastic tissue, the *internal elastic lamina*, which does not take the ordinary stain well, and appears as a light wavy band.

The MEDIA consists chiefly of circularly arranged involuntary nonstriated muscle tissue. The fibres are small and closely packed. Elastic fibres in moderate quantities are found between the muscle fibres in an artery of this size. Often a band of elastic tissue separates this layer from the adventitia. This is the *external elastic lamina*, but it is neither as thick nor so prominent as the internal. In some vessels (subclavian, especially) longitudinal muscle fibres are seen near the intima.

The ADVENTITIA, or EXTERNA, is a thick fibro-elastic coat,

and protects the vessel from undue dilatation. In some vessels, as renal and splenic arteries, longitudinal muscle fibres are found. This coat contains the larger trunks that

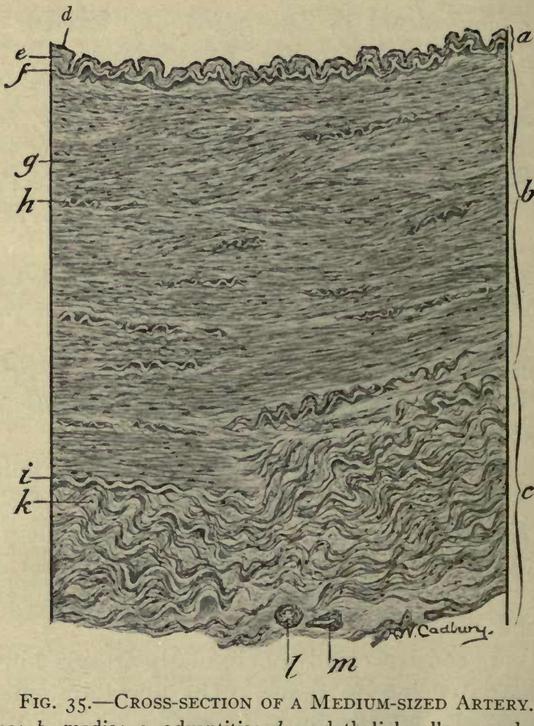


FIG. 35.—CROSS-SECTION OF A MEDIUM-SIZED ARTERY.

a. Intima; *b*. media; *c*. adventitia; *d*. endothelial cells; *e*. subendothelial tissue; *f*. internal elastic lamina; *g*. circular muscle tissue; *h*. elastic fibres; *i*. external elastic lamina; *k*. white fibrous tissue; *l*. arteriole; *m*. venule, vasa vasorum.

nourish the vessels, the *vasa vasorum*. The *nervi vasorum* are present also, and form branches that pass to the muscle coat.

IN LARGE ARTERIES the INTIMA is not so distinct and

gradually fades into the media. The *internal elastic lamina* is usually not present as such, but the elastic fibres have fused with the elastic tissue of the intima to form the *fenestrated membrane* of *Henle*. The media is not very muscular, as it contains a predominance of elastic fibres that give it an elastic, but not a contractile, character. The same is true of the large branches of the aorta as the iliacs, innominate, and common carotids. The adventitia differs but slightly.

In SMALL ARTERIES, the intima is proportionately thinner, and the elastic lamina quite prominent and thick. The media is proportionately thicker than in the other vessels. It contains very little elastic tissue, and no elastic lamina.

As the vessels become reduced, the intima is the first to suffer; the subendothelial tissue disappears, and the endothelial cells are seen to rest upon the elastic lamina. The media becomes attenuated so that only a single layer of muscle fibres is seen. This soon becomes reduced to a few stray fibres. The adventitia becomes greatly reduced, and is represented by a few bundles of fibrous tissue. This is practically the PRECAPILLARY VESSEL. It is succeeded by the **Capillary.**

2. The **Connecting** vessels (**Capillaries**) are merely delicate tubes consisting of a single layer of endothelial cells placed end to end, and held together by intercellular cement. The endothelium is held by some to be phagocytic. They are the smallest vessels, and anastomose freely to form loose or dense plexuses. The loosest mesh is found in muscles. At times they are very irregular, possessing dilatations. They are practically very thin animal membranes, and through their walls the liquid portion of the blood and the ameboid white blood cells have no difficulty in passing into the surrounding tissues. Small capillaries average 5 to 7 microns in diame-

ter, and cross-sections show that they are encircled by two endothelial cells. Large capillaries average 8 to 13 microns and are encircled by three to four endothelial cells. Stöhr claims that capillaries can contract as nerve endings are found in the cells.

In muscles, the capillaries run parallel to the course of the fibres, and are connected to one another by dilated vessels, or *ampullæ.* In the liver, adrenal, spleen and carotid gland, the endothelium of the capillaries is usually attached to the functionating epithelium or parenchyma. Such vessels are termed *sinusoids* (Minot). In the kidney are seen little arterial capillary tufts interposed between two arterioles. Such structures are termed *retia mirabilia.* In the penis, the arterioles empty into cavernous spaces, or *sinuses* without forming capillaries. In exposed regions, nose, ear, toes, kidneys and membranes of the nervous system, direct connections between arteries and veins exist. They are called *anastomoses.*

The **Afferent** vessels (**Veins**) have the same general structure as arteries, though the coats are all thinner, and collapse more readily; they carry the blood toward the heart.

The INTIMA often shows no internal elastic lamina; when present, it is not prominent. At intervals, this coat is thrown into folds called VALVES. These are duplications of the intima, and are usually arranged in pairs. At the place in which they are located, the vessels are usually slightly dilated. Valves occur in all the veins except the portal, pulmonary, hepatic, innominate, common iliacs, mesenteric, splenic and renal veins.

The MEDIA contains a very small amount of muscle tissue, but is reinforced by fibro-elastic tissue. In some veins, the muscle tissue is entirely wanting (brain and bones), while in others, longitudinal muscle fibres are present in this coat.

The lack of muscle tissue accounts for the collapsibility of these vessels.

The ADVENTITIA is the most prominent coat, and may possess longitudinal muscle fibres. It is similar, in structure, to that of the arteries.

Blood-vessels are nourished by *vessels* that pierce the

FIG. 36.—PORTION OF A CROSS-SECTION OF A HUMAN VEIN.

A. Intima; B. Media; C. Adventitia—*a*. internal elastic lamina; *b*. smooth muscle fibres; *c*. white fibrous connective tissue; *d*. smooth muscle fibres in the adventitia (*Stöhr's Histology*).

adventitia and send branches to the media, the *vasa vasorum*. The intima is nourished by the blood that flows over it.

The NERVES are chiefly sympathetic, and are distributed to the media and adventitia. They are the *nervi vasorum*.

Vessels are often the centers of extensive *lymphatic channels* that lie in the adventitia.

Table of comparison of arteries and veins:—

CHARACTER.	ARTERIES.	VEINS.
Coats.	Three.	Three.
Size.	Thick.	Thin.
Intim.	Elastic lamina prominent.	Not prominent; may be absent.
Media.	Mainly smooth muscle.	Little muscle, mainly white fibrous tissue.
When empty.	Do not collapse readily.	Collapse readily.
Valves.	Absent.	Usually present.
Course of the blood.	From the heart.	Toward the heart.
Character of the blood.	Oxygenated (with exception of that in the pulmonary artery).	Deoxygenated (with exception of that in the pulmonary veins).

The **Blood** is the *only liquid connective tissue.* It is composed of CELLULAR ELEMENTS, THE CORPUSCLES, and the INTERCELLULAR SUBSTANCE, the LIQUOR SANGUINIS.

The CELLULAR ELEMENTS are of three varieties, the RED CELLS, WHITE CELLS and PLATELETS.

The RED CELLS, or ERYTHROCYTES, are *non-nucleated, bell-shaped* elements averaging 7 to 8.5 microns in diameter. The bell-shape is not seen unless the necessary precautions are exercised, that is to fix the blood before it becomes exposed to the air (see **Blood Technic,** p. 27). These cells have been studied under various conditions by Weidenreich and Lewis and the author has found that they are to be readily studied in fetal tissues. Upon exposure to air these bell-shaped cells collapse and this accounts for the usual description as that of a biconcave disc. In the normal blood these cells form rouleaux and this is said to be due to the cells fitting into one another. When exposed to air these cells collapse and resemble rolls of coins on edge.

Under the microscope each cell is pale straw-colored or greenish. It consists of a framework, the *stroma*, that contains an inorganic compound that carries the oxygen; this is the *hemoglobin*. The presence of a cell membrane is still a matter of dispute.

Some cells average from 5.5 to 7.5 microns, and are called *microcytes*, while those over 8.5 microns are *macro-*

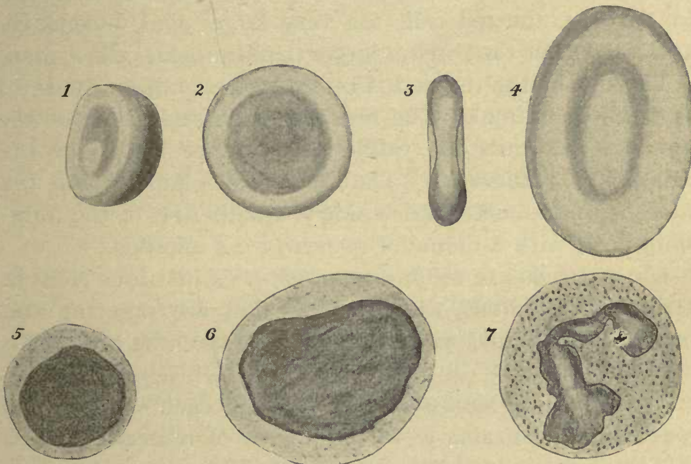


FIG 37.—BLOOD CELLS.

Red blood cells 1, 2, 3 and 4 1, Bell-shaped red blood cell of man; 2, surface view of collapsed bell-shaped cell; 3, side view of 2; 4, surface view of red blood cell of the frog.

White cells 5, 6 and 7. 5, Small lymphocyte; 6, hyalin cell; 7, finely granular oxyphil.

cytes. Bethe found the various red cells in the following proportions: 6.92 microns, 42 per cent.; 7.26 microns, 28 per cent.; 8.58 microns, 16 per cent.; 6.6 microns, 8 per cent.; 9.24 microns, 6 per cent.

In normal blood, the cells tend to form rolls, or *rouleaux*. Under the same condition, 5,000,000 corpuscles are found,

per cubic mm., in the male, and about 4,500,000 in the female.

Nucleated red cells, or *erythroblasts*, are found in the fetus, in bone-marrow and the spleen. The cell of average size is called a *normoblast*, the *smaller*, a *microblast*, and the *larger*, a *macroblast*. In *fishes*, *reptiles*, *birds* and *amphibians*, the *red cells are nucleated*. In all *mammals*, they are *circular*, except in the camel family, in which they are oval. In the *frog*, the red cells are very large, oval, biconcave, nucleated discs that are far larger than the same cells in man.

The size of the red cell is by no means proportionate to that of the animal. The musk deer possesses one of the smallest (2.4 microns), while the proteus has about the largest (62.5 microns). That of the elephant is but 9.2 microns in diameter, and beside it stands that of the humming bird, with a diameter of nearly 9.4 microns.

The red cells are more numerous in carnivorous than in herbivorous animals, while in birds they are larger in size. In the amphibians, where the size is great, the number is small.

According to Malassez and Hayem, each cu. mm. of goat's blood contains 18 to 19 millions of red cells; birds 2 to 3 millions; reptiles 0.5 to 1.6 millions; frogs 400,000; proteus 36,000; bony fishes 1 to 2 millions; torpedo 140,000.

WHITE BLOOD CELLS, OR LEUKOCYTES, are large, pale cells readily distinguished from the above. About 5,000 to 8,000 are found in each cubic mm. of blood, and some of the varieties have the powers of motion and phagocytosis.

They are classified as follows:

1. LYMPHOCYTES (SMALL LYMPHOCYTES).
2. HYALIN CELLS (LARGE LYMPHOCYTES).
3. POLYMORPHONUCLEAR LEUKOCYTES, OR FINELY GRANULAR OXYPHILS (*Formerly neutrophil*).

4. COARSELY GRANULAR OXYPHILS (*Formerly acidophil*).
5. FINELY GRANULAR BASOPHILS.
6. COARSELY GRANULAR BASOPHILS.

1. The LYMPHOCYTES average 5 to 11 microns. Each consists of a large darkly staining nucleus surrounded by a narrow rim of faintly stained protoplasm. It is both ameboid and phagocytic, and constitutes about 15 to 30 per cent. of all the white cells.

2. The HYALIN CELL averages 11 to 15 microns. Both nucleus and protoplasm stain but faintly, hence the name. In the protoplasm some basophilic granules are occasionally seen. It is *actively ameboid* and *phagocytic*. It represents 2 to 6 per cent. of the white cells.

3. POLYMORPHONUCLEAR LEUKOCYTES, or FINELY GRANULAR OXYPHILS, F. G. ACIDOPHILS, or F. G. EOSINOPHILS, average 7.5 to 11 microns. The nucleus has many shapes, as U, V, W, etc., and may even be divided in a number of segments (polynuclear). The protoplasm contains a number of fine granules that take the acid stain deeply. These granules were at one time regarded as *neutrophilic*, and the cells were called *neutrophils*. They are *actively ameboid* and *phagocytic*, and represent 60 to 72 per cent. of all leukocytes.

4. The COARSELY GRANULAR OXYPHIL, C. G. ACIDOPHIL, or EOSINOPHIL, is about 7 to 10 microns in diameter. The protoplasm contains a few large granules that take the acid stain deeply. It was formerly called *acidophil*, or *eosinophil*, and is *actively ameboid*, but *not phagocytic*. It represents .1 to 4 per cent. of the leukocytes, though rarely over 2 per cent. except in childhood.

5. The FINELY GRANULAR BASOPHIL resembles GROUP 3, except that the granules take a basic stain, and are present to the extent of .1 to 1 per cent., but usually under .25 per cent.

6. The COARSELY GRANULAR BASOPHIL is said to be absent from normal blood. It is a relatively large cell, and is also called the *mast cell.*

Another cell that is usually described among the leukocytes is the *myelocyte*, or *marrow cell.* This cell is *not a normal constituent of the blood*, but is found there in certain blood diseases. (See Bone-marrow, p. 73.)

The BLOOD PLATELETS, or THROMBOCYTES, are small (2 to 4 microns), oval or circular discs, capable of ameboid movement. They number about 200,000 to 300,000 per cubic mm. Their function and origin are unknown. They can readily be found in blood fixed in a 1 per cent. osmic acid solution.

In certain diseases the platelets are increased while in others they are diminished.

According to Helber, platelets are not found in the blood of frogs or birds.

The INTERCELLULAR SUBSTANCE, or LIQUOR SANGUINIS, contains the salts of the blood. Its density is such that the cells retain their normal shape. If, however, solutions are added that differ in density, the action upon the cells is characteristic.

Upon the addition of strong *salt solution*, the cells become irregular in outline, and are *crenated.* If *water* be added, it dissolves the hemoglobin, and the cells *swell* and become spherical, but, as a rule, *are not destroyed.*

The action of *acetic acid* is important. The addition of a .3 per cent. solution *decolorizes* the red cells and renders the white cells *more distinct.* This is made use of in **Hematology** for the purpose of counting the white cells, in a fresh condition.

When blood *clots*, fibrin is precipitated, and this entangles the corpuscles.

HEMOGLOBIN is an organic compound of iron, and, as it

Teichmann's crystals

exists in the blood, it cannot be readily studied. Its conversion into the crystalline state is not difficult.

Hemoglobin crystals will be formed if a drop of defibrinated blood be mixed with a drop of Canada balsam, or clove oil, and covered with a cover-glass. They are large, red, tetrahedral crystals.

Hemin crystals may be prepared by adding a small crystal of salt and two drops of glacial acetic acid to a little dried blood, and heating until the mixture boils. During this process it should be covered. When cool, small

Fig. 38.
1. Hemin crystals of man (×560); 2. crystals of common salt; 3. hematoid crystals of man (*Stöhr's Histology*).

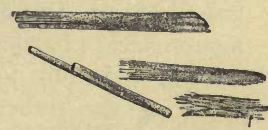


Fig. 39.—Hemoglobin Crystals of a Dog (×100); a crystal separating into fibres (*Stöhr's Histology*).

brownish crystals will be found. These may be single or grouped in the form of rosettes, and are known as *Teichmann's crystals*.

Among the blood-making organs are placed the coccygeal and carotid glands.

The *former*, luschka's gland, is found in front of the coccyx, and is joined to the middle sacral artery. It is surrounded by a fibrous sheath, which sends in septa that divide the organ irregularly into *areas*, or *compartments*. The latter contain groups of polyhedral cells surrounded by dense plexuses of capillaries. Nonmyelinated nerve fibres are numerous.

Luschka's or Coccygeal

The CAROTID GLAND is found at the bifurcation of the common carotid artery, and its structure is the same as that of Luschka's gland.

HEMOLYMPH NODES.—These organs vary in size from a pin head to a large bean and are found in abundance in the retroperitoneal and cervical regions and less numerous elsewhere. Each is surrounded by a capsule of white fibrous and yellow elastic tissues, containing a little smooth muscle tissue; trabeculæ pass in and form the framework of the organ. In the framework are found *red* and *white* blood-cells. Of the latter, the lymphocytes are the most numerous; besides these hyalin, finely granular oxyphils and basophils are found in varying numbers. In addition, mononuclear phagocytes that contain pigment and disintegrating red cells are seen. Beneath the capsule and following the trabeculæ to the hilus are seen sinuses that do not contain lymph but blood.

These organs usually possess no lymphatics. The blood-vessels enter at the hilus and form capillaries within the organ; these capillaries communicate with the blood sinuses. The larger views are in the trabeculæ and end in thin-walled lacunæ that possess perforated walls, by means of which they communicate with the blood sinuses.

Certain atypic organs possess lymphatics. *Nerves* are present and probably pass to the smooth muscle tissue.

Some of these structures resemble the spleen in structure, others the marrow and still others ordinary lymph nodes.

Parasympathetics, or Aortic Bodies.—These are two to four brownish bodies found in the neighborhood of the inferior mesenteric artery and closely related with the aortic sympathetic plexus. Each is surrounded by a capsule of white fibrous connective tissue that sends in trabeculæ that form the framework of the organ. In the meshes of this framework are found the epithelium which consists of

groups of polygonal or cuboidal cells closely packed and of the chromaffin type.

The *blood-vessels* derived from the aorta, or inferior mesenteric artery, follow the trabeculæ and form a rich capillary plexus around the epithelial cell-groups.

The *nerves* are from the sympathetics and their relation and arrangement is similar to the nerves of medulla of the adrenal. These organs are found chiefly in childhood.

Chromaffin ? Chrom— Sol

Cells taking stain

CHAPTER VIII.

THE LYMPHATIC SYSTEM.

The **Lymphatic System** includes the **Lymphatic** and **Thoracic Ducts, capillaries** and **intermediate vessels,** and a number of organs, **Lymph Node (Lymphatic Gland), Spleen** and **Thymus Body.**

The **ducts** resemble veins more than arteries. Their walls are thin, and they possess valves. The arrangement of the muscle, and the distribution of the nerves, are like those of an artery.

Lymph capillaries are much larger than those of the vascular system, measuring 30 to 60 microns in diameter.

Lymphoid tissue is arranged in four ways, DIFFUSE, SOLITARY FOLLICLES, AGMINATED FOLLICLES AND LYMPH NODES, or LYMPHATIC GLANDS. The first three have been considered under **Lymphoid Tissue.** (See **Connective Tissues,** p. 66).

Lymph Nodes, or **Glands,** are small, bean-shaped organs, surrounded by a CAPSULE, and composed of CORTEX, MEDULLA and HILUS.

The CAPSULE consists of white fibrous tissue and contains some yellow elastic and smooth muscle tissues; beneath is a lymph space or sinus. From the inner surface of the capsule, *trabeculæ* are sent into the cortex, and these divide the latter into a number of masses called *secondary follicles*, or *nodules*. The lymph space continues along the trabeculæ.

The CORTEX contains the *secondary nodules* and *trabeculæ*. The former consist of dense lymphoid tissue, and

contain a germinal center. The cells are chiefly *lymphocytes*, which are arranged in concentric layers around the periphery. Other cells of the *hyalin* variety are found in the central portion. During gestation, nucleated red cells may be present. The follicles continue into the center of the node as the *medullary cords*.

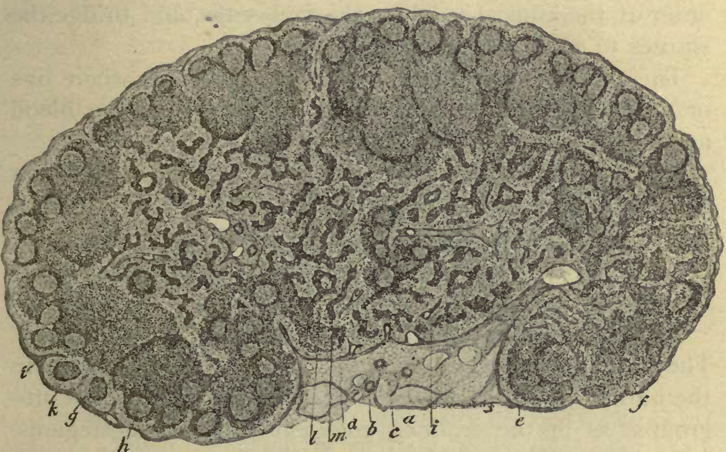


FIG. 40.—LONGITUDINAL SECTION OF A LYMPH NODE.

a. Hilus; *b*. arteriole; *c*. venous sinuses; *d*. adipose tissue; *e*. secondary nodule of cortex; *f*. vein in medulla; *g*. subcapsular lymph sinus; *h*. germinal center of secondary nodule; *i*, *i*. trabeculæ; *k*. capsule; *l*. lymph sinus; *m*. medullary cord.

The *trabeculæ* separate the follicles from one another, and pass into the medulla surrounded by the lymph space.

The MEDULLA consists of the *medullary cords* and *trabeculæ*.

The *cords* are the band-like continuations of the secondary follicles, and are separated from the trabeculæ by the lymph spaces that accompany the latter. They consist of *dense lymphoid tissue*, supported by *reticulum*. At the hilus, the medulla comes to the surface.

The HILUS is a scar-like depression at one side, where the vessels enter and leave. At this place, the secondary nodules are wanting, and the medulla comes to the surface.

The *arterial vessels*, to a great extent, enter at the periphery of the node. Their branches continue into the trabeculæ, and then pass into the follicles. Those that enter at the hilus also follow the trabeculæ, and bridge the sinuses to enter the lymphoid tissue.

The *venous* radicals all pass toward the hilus, where one or more vessels may be formed that carry all the blood away.

The *afferent lymph vessels* pierce the capsule at different points, and empty into the capsular sinus. The lymph passes down along the trabeculæ, and filters through the organ. All the lymph is collected into one or more *efferent* vessels that leave at the hilus.

Lymph nodes are the highest form of lymphoid tissue. They are scattered throughout the lymphatic system, in the pathways of the vessels. They are often collected into groups, as in the *axillary*, *inguinal* and *femoral* regions.

Lymph nodes are uncertain structures, as they may disappear early, or change from place to place. They make the white blood-cells, filter the lymph, are the centers of cell destruction, and may possibly give rise to red blood-cells, as in the female during pregnancy.

SPLEEN.

The **Spleen** is a lymphoid structure, surrounded by a **capsule** of dense white fibrous tissue that contains involuntary non-striated muscle fibres, and limits the **splenic substance.**

The **capsule** sends in *trabeculæ* that divide the organ irregularly into compartments. At one side is a depression, the HILUS, at which the vessels enter and leave.

The **splenic substance** consists of two main portions, the PULP and MALPIGHIAN or SPLENIC CORPUSCLES.

The PULP is composed of *diffuse lymphoid tissue, disintegrating red cells, nucleated red cells* and some large *polynuclear elements*. To the red cells the peculiar color is due, and the organ has been called the "grave-yard of the red cells." The cells are supported by retiform connective tissue.

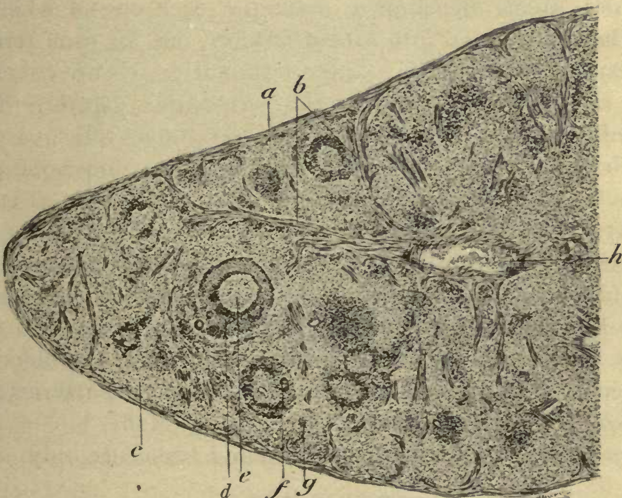


FIG. 41.—SECTION OF SPLEEN.

a. Capsule; *b*. trabeculæ, longitudinal section; *c*. pulp; *d*. splenic corpuscle; *e*. germinal center of corpuscle; *f*. eccentric arteriole in corpuscle; *g*. trabecula, cross-section; *h*. blood-vessel.

The SPLENIC CORPUSCLES are solitary follicles and consist of dense lymphoid tissue. They differ from the ordinary follicle in possessing an *eccentrically-placed arteriole*. This lymphoid tissue is held to be in the adventitial sheath of the arteriole, and forms a spherical mass at the bifurcation of the vessel. These follicles usually show germinal centers.

The *circulatory system* of the spleen is peculiar in being an open one. *Capillaries, as such, do not exist,* and the arterioles and venules are connected by blood spaces, or *ampullæ.*

The splenic artery enters at the hilus, and breaks into branches that follow the trabeculæ. Of these, some quickly pass into the pulp, while others follow the trabeculæ to their smallest divisions. The spleen is divided into lobules, about one mm. in diameter, each one of which is further subdivided into *histologic units,* one for each terminal artery, or *ampulla.* These terminal vessels are covered by a lymphatic sheath, the *ellipsoidal sheaths.* The terminal ampullæ are *porous,* and continue as veins.

The spleen is subject to rhythmic contractions, one per minute, and about 18 per cent. of its volume is lost at each contraction. These are produced by the involuntary muscle in the capsule and trabeculæ. When the cardiac impulse sends the blood into the arteries, the blood passes into the ampullæ, and through the porous walls into the pulp. When the rhythmic contractions occur, the blood is forced into the veins, and, at the same time, the arteries are closed. This shows an open circulation (Mall).

Lymphatics occur in the capsule and trabeculæ only.

THYMUS BODY.

The **Thymus Body** is essentially a lymphoid structure, though it undergoes peculiar changes in its life history.

It originates as a *true gland* (epithelial organ), but soon leukocytes infiltrate it, and cause the disappearance of the epithelium, except small islands. After the sixth year, it generally undergoes further change. The *lymphoid tissue is gradually replaced by adipose tissue,* so that an old thymus will show but little lymphoid tissue.

This organ is surrounded by a *capsule* of white fibrous

tissue that sends in septa, which divides the organ into LOBES and LOBULES.

Each LOBULE consists of *cortex* and *medulla*.

The CORTEX is composed of *dense lymphoid tissue*, and stains deeply, owing to the large number of leukocytes present. The MEDULLA consists of *diffuse lymphoid tissue*, and takes, therefore, a lighter stain. The supportive tissue is *reticulum*.

FIG. 42.—SECTION OF THE THYMUS BODY OF A CHILD.

a. Capsule; *b*. interlobular connective tissue; *c*, *c*. adipose tissue; *d*. blood-vessels in interlobular tissue; *e*. cortex; *f*. medulla; *g*. blood-vessel in lobule; *h*, *h*. corpuscle of Hassal; *i*. corpuscle of Hassal magnified.

In the medulla, are found small, peculiar bodies, consisting of concentrically arranged epithelial cells; these are the *thymic corpuscles*, or *corpuscles of Hassal*. They are supposed to represent the remains of the epithelium, though some hold that they represent endothelium of blood-vessels. These bodies are encapsulated, and may be compound.

The *blood-vessels* pierce the capsule, and form branches in the interlobular connective tissue. From these, capillaries enter the lobules and are distributed to the lymphoid tissue.

CHAPTER IX.

ALIMENTARY TRACT.

The **Alimentary Tract** starts at the lips, and extends to the anus. It receives the food, digests it and casts off that which is undigested. The various portions perform different functions, and the lining cells differ accordingly. The inner coat is a *mucous membrane* that gives rise to *glands*, which are devices of nature for increasing the secretory surface. The absorptive surface is increased by prolongations of the mucosa into the lumen of the organ (villi of the small intestine).

The **Lip** is covered externally by SKIN, and internally by MUCOUS MEMBRANE. Between these, are found connective tissue and muscle.

The SKIN consists of two portions, the *epithelial*, or *epidermis*, and the *connective tissue portion*, or *derma*.

The *epidermis* is composed of *stratified squamous cells*, of which two layers, the *stratum corneum* and *stratum Malpighii* are distinct. The *stratum corneum* is the *outer*, and consists of nonnucleated scales; the *stratum Malpighii* is the *genetic* portion. Its lowest cells rest upon a *basement membrane*, and are columnar in shape. Those above are polyhedral; the latter become more flattened as the corneum is approached. The *derma* consists of white fibrous connective tissue supporting blood-vessels, nerves and lymphatics. Beneath the epithelium it is thrown into waves called *papillæ*.

The *mucous* surface is also lined by *stratified squamous* cells, that differ from the outer, however, in being larger

and less readily stained. The cells rest upon a *basement membrane*, beneath which is the *tunica propria*, composed of papillated, delicate fibro-elastic tissue.

Between the tunica propria and skin, are found connective tissue and voluntary striated muscle. Near the tunica propria are to be seen small, compound tubular glands that open upon the mucous surface. At the margin of the lip these two surfaces join, and this is the *muco-cutaneous junction;* here the epithelial layer is quite thick, and the cells are larger and bladder-like, resembling the epitrichial cells of the fetus.

Blood-vessels are found in great abundance, and form dense plexuses, especially around the glands.

The **Mouth** is lined by a MUCOUS MEMBRANE, consisting of *stratified squamous cells* resting upon a *basement membrane* and *tunica propria.* Here and there are found small glands of the same nature as those found in the lips.

THE TEETH.

The **Teeth** are the chief organs of mastication and are adapted for cutting, grinding, holding, etc. Each consists, anatomically, of CROWN, that portion above the gum; ROOT OR FANG, that portion in the jaw; NECK, the narrow portion between the preceding, covered by the gum.

Histologically considered, there is the ENAMEL that covers the crown; the DENTIN that forms the bulk and gives the shape of the tooth; the CEMENTUM that covers the dentin of the fang; the PERIDENTAL MEMBRANE that surrounds the root and holds the tooth in place; the PULP that occupies the pulp cavity and is the nutritive and sensitive portion of the organ. In the root of the tooth is a canal that leads into the PULP CHAMBER; this is the ROOT CANAL.

The enamel is the hardest substance in the body and

forms a cap-like covering, of varying thickness, of the dentin. It is thickest at the cutting or occlusal surface of the teeth and diminishes in thickness as the root is approached. It is said to consist of 97 per cent., or more, of inorganic matter and 3 per cent., or less, of organic matter.

The **enamel** consists of hexagonal enamel prisms that are arranged perpendicular to the surface of the dentin, and represent modified epithelial cells. Each ENAMEL PRISM OT FIBRE has a wavy or tortuous course with its inner end fitting into a slight depression in the dentin. The prism is of the same diameter throughout, though the sides may not be straight and even. As a result, near the surface of the tooth shorter additional prisms are found and these are the SUPPLEMENTAL PRISMS. The prisms seem to be held together by a transparent cement which is apparently inorganic in composition. In a prepared section of the tooth are seen some *brown striations* that run almost parallel to the surface of enamel or dentin and in the latter instance may run the entire extent of the crown. These are the "brown striæ of Retzius." The cause of these striæ is still in dispute. Tomes believes that they represent successive positions of the enamel cap.

When studied with reflected light the "lines of Schreger" are seen in the enamel. These are apparently due to various directions taken by the different bundles of enamel prisms, and are well marked near the surface of the dentin and less so toward the surface of the enamel.

Dentin.—This portion forms the bulk of the tooth and gives it its shape. It is yellowish-white in color, harder than bone, and represents ivory. It is everywhere covered by either enamel or cementum. It is composed of about 72 per cent. of inorganic matter and of about 28 per cent. of organic matter.

The parts of importance are the DENTINAL SHEATHS,

MATRIX, and DENTINAL FIBRES. The DENTINAL SHEATHS, or NEUMANN'S SHEATHS, are delicate tube-like masses of

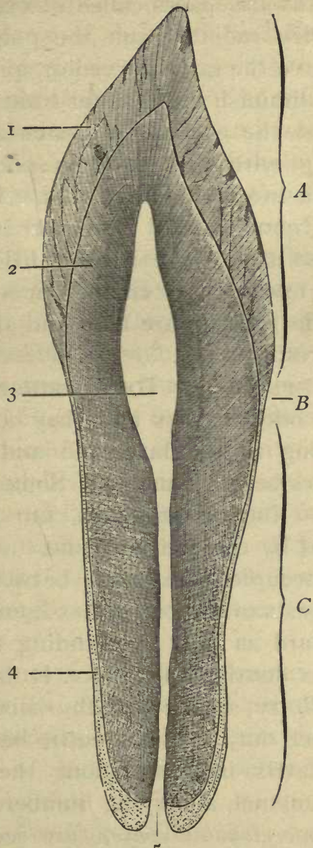


FIG. 43.—LONGITUDINAL SECTION OF AN INCISOR TOOTH
A. Crown; *B*. Neck; *C*. Fang; 1. enamel; 2. dentin; 3. pulp-cavity; 4. cementum; 5. root-canal (*after Stöhr's Histology*).

dense dentin that seem indestructible and will persist when the matrix has been destroyed. They extend in a curved

or spiral course from the pulp cavity to the enamel or cementum, diminishing in diameter as they pass outward. Within the sheaths are spaces called DENTINAL TUBULES or CANALICULI. They radiate from the pulp cavity to the periphery and have the same curved or spiral course of the sheaths. They diminish in diameter from within outward, and terminate at the enamel or cemental surface either by anastomosing with one another, ending bluntly or opening into the interglobular spaces. The pulp cavity end is usually funnel-shaped and the tubules here are closely packed so that there is very little matrix. The tubules branch toward the enamel or cementum. The curvatures of the tubules are long and short, or primary and secondary, respectively.

The DENTINAL FIBERS, or TOME'S FIBRES, represent the processes of the odontoblasts and they occupy the dental tubules, branching as the latter do and diminishing in size as the tubules become smaller. Some claim that they do not belong to the odontoblasts, but represent nerve tissue surrounded by connective tissue.

The MATRIX occupies the space between the dentinal sheaths. It consists of a more or less homogeneous dentin that is not so hard as that surrounding the canaliculi in the form of the dentinal sheaths. It is less abundant near the pulp cavity, as the sheaths here are very close together. Farther out, as the sheaths become smaller in diameter, the matrix increases along the margin of the dentin near the enamel, a varying number of small irregular spaces, the *interglobular spaces*, are seen; these represent areas of imperfect calcification and they are filled with a gelatinous substance. Between dentin and cementum these spaces are smaller, and under low power give a granular appearance to the area; this represents "Tome's granular layer."

Cementum.—This is a bone-like substance that covers the root of the tooth. It consists of about 66 per cent. inorganic matter and 34 per cent. organic matter. It is thickest at the apex of the tooth and becomes gradually thinner as the cervix or neck is approached and ends at the lower margin of the enamel. It resembles bone very closely, contains LACUNÆ CANALICULI and LAMELLÆ, but no Haversian systems. The LAMELLÆ are about the same in number but thicker at the apex than near the cervix. This applies to young teeth. In older teeth the layers are not only much thicker near the apex but are also more numerous, the shorter added lamellæ constituting *supplemental lamellæ*. The layers may or may not run parallel to the dentin. Passing through the lamellæ at varying intervals are fibres that seem to bind the layers together, resembling the fibres of Sharpey. Between the lamellæ are irregular spider-like spaces that resemble, but vary in size, shape and number of canaliculi, those of bone; they lie partially in one layer and partially in another and their long axes are parallel to the surface of the tooth. Extending out from the lacunæ are the CANALICULI which usually are directed peripherally, though some are seen extending in all directions.

The CEMENTOBLASTS occupy the lacunæ. They are oval, stellate, or elongated elements and usually correspond in direction to the lacunæ. The processes vary in length and form, and most of them extend toward the periphery, following the canaliculi.

Dental Pulp.—The **Pulp** is the highly vascular and sensitive mucous connective tissue that occupies the *pulp cavity*, or *chamber* and root canals and is concerned with the nutrition and growth of the tooth. It is composed of cells and intercellular substance and contains blood-vessels and nerves.

The cells are of various varieties, the most important of which are the ODONTOBLASTS. These cells are found upon the surface of the pulp and form a continuous layer of cells one layer deep. The cells are elongated flask-shaped elements from which three sets of processes extend. These are *dentinal*, *pulpal* and *lateral*. The *dentinal process* or processes arise from the peripheral end of the cell and extend into the dentinal tubules, and they have been described under the dentin. The *lateral processes* pass from the sides of the cells to the neighboring cells, while the *pulpal processes* extend from the central ends of the odontoblasts to the deeper cellular elements of the pulp. The nucleus occupies the end of the cell next the pulp reticulum. Beneath the layer of odontoblasts there is a narrow layer of tissue almost devoid of cells, then an area of which the cells are quite numerous, and again a region, the center of the pulp, in which there are very few cellular elements. The cells are spindle-shaped, stellate and spheroid in form and possess many or few hair-like processes that pass in all directions.

The ARTERIES, *apical*, of the pulp are derived from a branch that enters the root canal of the tooth; as this vessel passes toward the pulp chamber it gives off branches that form plexuses parallel to the long axis of the tooth; ultimately forming rich capillary plexuses in the neighborhood of the odontoblastic layer. The blood is collected by venous channels that anastomose freely and empty into one channel that leaves through the root canal.

The NERVES, one or more, pass through the root canal giving off a few fibres here; in the pulp chamber branches are distributed in every direction forming arch plexuses, after losing their myelin sheaths, beneath the layer of odontoblasts. From this plexus fibres are said to pass between the odontoblasts to end in bulbous enlargements

within the central ends of the dentinal tubules. Magitot claims, however, that the dentinal fibres are continuations of the nerve fibres.

The **Peridental,** or **Alveolodental membrane,** is a highly vascular and sensitive white fibrous tissue membrane that lines the alveolar processes of the jaw and covers the roots of the teeth. It is thickest at gum and apical portions and thinnest in the middle. The fibrous elements are bundles of white fibrous tissue that pass into the cemental layers on the one hand and into the bony tissue of the jaw on the other hand, resembling Sharpey's fibres. In general around the apex of the tooth the fibre bundles are arranged fan-like and are directed upward and outward. In the body of the tooth the fibre bundles pass directly outward from the cementum to the alveolar wall and are largest and strongest here. At the gum margin the fibre bundles pass outward and are lost in the fibrous tissue of the gum, or pass toward the adjacent tooth as the case may be.

Upon the inner surface of the membrane are found the *cementoblasts;* these are irregular flattened elements possessing a clearly defined nucleus and numerous delicate irregular processes that extend in various directions. They are evenly distributed. Upon the opposite (alveolar) surface of this membrane are the *osteoblasts* that form the bone of the jaw. In the meshes of the fibre bundles are found *fibroblasts* or connective-tissue cells and some *osteoclasts* or bone-destroying cells. The latter are large, fairly regular, oval or round cells that possess several nuclei and usually have no processes.

The *arteries* are derived from the apical artery and pass up parallel to the long axis of the tooth, giving off branches at intervals; these form capillary plexuses beneath the alveolar and cemental side of the membrane. The blood

Nasmyths membrane

is collected by venous channels that ultimately empty into the apical vein.

The *veins* are likewise derived from those at the apex and are distributed somewhat like the arteries.

The *functions* of the alveolodental membrane are *physical* and *sensor*. It holds the tooth in place, returns it to its normal position when slightly rotated or displaced; upon one side it forms cementum and upon the other it forms bone.

Nasmyth's Membrane.—This is a thin indestructible membrane covering the enamel of the tooth. It is said by some to be the remains of the enamel organ, while others claim it is a continuation of the cementum. The *former* seems the more probable origin.

THE TONGUE.

The **Tongue,** like the **Teeth,** occupies part of the mouth cavity. It is covered by a MUCOUS MEMBRANE that consists of *stratified squamous* cells, *basement membrane* and *tunica propria*, which, along the sides and base, is papillated. The upper surface, or *dorsum*, is characteristic. Its apical two-thirds is covered by minute projections, called *papillæ;* of these there are three varieties, FILIFORM, FUNGIFORM and CIRCUMVALLATE. The central portion consists chiefly of voluntary striated muscle.

The FILIFORM PAPILLÆ are *cone-shaped projections* of the *tunica propria*, covered by the *stratified squamous* cells, the outer ones of which are hard and horny. The central part of a papilla consists of white fibrous tissue, which is thrown into small *secondary papillæ* that are not visible externally. These papillæ are the most numerous, and are scattered over the whole of the apical two-thirds. They are directed backward, and are the ones that produce the

scratching sensation when the hand is licked by a lower animal.

The FUNGIFORM PAPILLÆ are flat-topped, table-like structures, in which the sides are parallel. They have secondary papillæ, and are scattered like the filiform variety, but are less numerous.

The CIRCUMVALLATE PAPILLÆ are the most important. While the top is flat, the sides usually converge and give this variety a narrow base. SECONDARY PAPILLÆ are found *only on the upper portion.* Each papilla is surrounded by a little *vallum*, or *ditch*, hence the name.

These papillæ are the least numerous, and are found only in one area. Ten to fifteen arrange themselves like a letter V, with the apex at the *foramen cècum*, a little depression that lies at the boundary of the apical two-thirds and basal one-third of the tongue. These papillæ contain TASTE-BUDS along their sides.

The TASTE-BUDS are the *organs of taste*, lie in the epithelial portion of the sides, and have a definite structure.

They are *barrel-shaped*, and open at the exposed ends. Each consists of two kinds of cells, *outer* (stave-like), the *sustentacular*, or *supporting cells*, and the *inner*, *neuro-epithelial* elements.

The SUSTENTACULAR cells are flat and stave-like elements possessing a prominent nucleus. The *neuro-epithelial* elements are spindle-shaped, and each ends in a minute, hair-like process, the *gustatory hair*, that projects through an opening in the barrel, the *gustatory pore*. The nerve fibre that extends to each bud forms branches, one of which is supplied to each neuro-epithelial cell.

Beneath the mucosa is found the MUSCULATURE of the tongue. This consists of the voluntary striated variety, arranged *longitudinally*, *vertically* and *transversely*. The longitudinal fibres are arranged in bundles that lie beneath

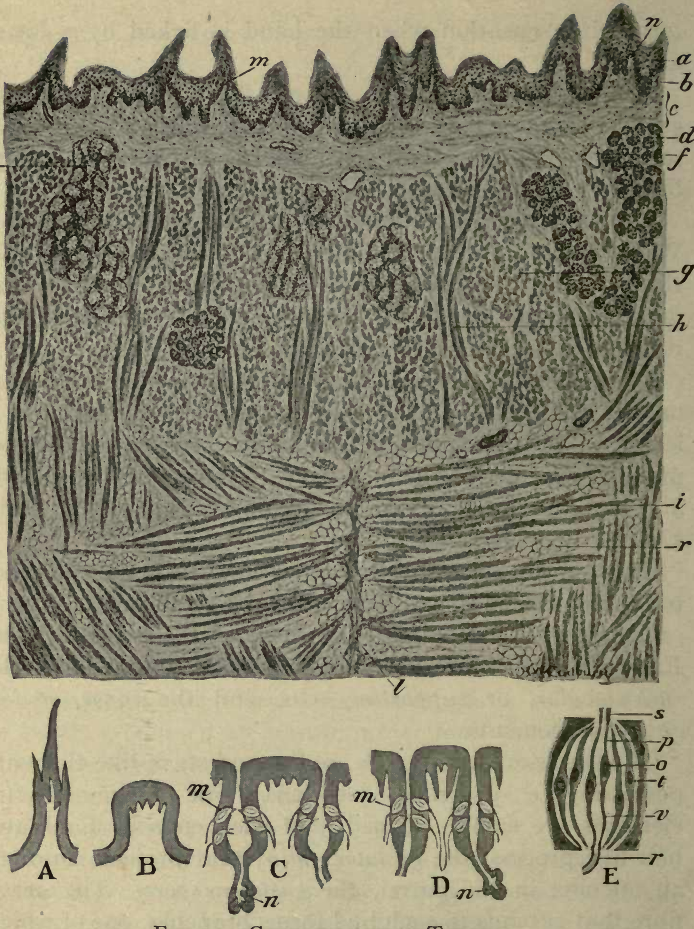


FIG. 44.—CROSS-SECTION OF TONGUE.

a. Stratified squamous cells; *b*. basement membrane; *c*. tunica propria; *d*. serous glands; *e*. mucous glands; *f*. venule; *g*. longitudinal muscle fibres; *h*. vertical muscle fibres; *i*. transverse muscle fibres; *l*. septum; *m*. filiform papilla; *n*. secondary papillæ; *r*. adipose tissue. A. Filiform papilla. B. Fungiform papilla. C, D. Circumvallate papillæ—*m*, *m*. taste-buds; *n*, *n*. glands. E. Taste-bud—*o*. nucleus of neuro-epithelial cell; *r*. nerve fibre; *s*. gustatory hair; *t*. sustentacular cell; *v*. neuro-epithelial cell.

the tunica propria and extend around the tongue. They are separated by small bundles of vertical fibres. In the center, the fibres are vertical, oblique and transverse, and are separated in the middle line by a little partition, or *septum*. This consists of white fibrous tissue, and arises at the base, but does not reach the tip. It varies in height, being higher in the middle than at either end. In the muscular portion, small glands are often found. Occasionally, branched muscle fibres are found.

The *true base* of the tongue, the *posterior one-third*, *possesses no papillæ*. It contains small salivary glands and collections of lymphoid tissue called the *lingual tonsils*.

The *blood-vessels* are quite numerous; the capillaries extend into the papillæ and between the muscle fibres and form plexuses around the glands.

The *lymphatics* are in the base, and are found quite numerous in the tunica propria, where they receive branches from the papillæ.

THE TONSILS.

The **Tonsils** are found just between mouth and pharynx, and are essentially *lymphoid structures*.

They are covered, upon their exposed surface, by *stratified squamous* cells that dip down into the organ in the form of irregular tubes called the *tonsillar crypts*. The organ is separated from the surrounding tissue by a layer of white fibrous tissue, the *capsule*, that sends in trabeculæ, which form the main framework of the organ. The bulk of the tonsil consists of lymphoid tissue, in the form of the *diffuse variety* and *solitary follicles*. The latter show germinal centers, and are found chiefly around the crypts. The supportive tissue is of the *retiform variety*. Leukocytes may be seen on their way to the crypts, where they become the *salivary corpuscles*.

Blood-vessels, and *especially lymphatics*, are numerous. The vascular capillaries ramify the lymphoid tissue, while the lymph channels surround the follicles and form a peripheral vessel beneath the fibrous capsule.

FIG. 45.—VERTICAL SECTION OF HUMAN TONSIL.

a. Stratified squamous epithelium; *b*. basement membrane; *c*. tunica propria; *d*. trabeculæ; *e*. diffuse lymphoid tissue; *f*. adipose tissue; *h*. capsule; *i*. glands; *k*. muscle; *l*. blood-vessel; *m*. epithelium of crypts; *q*, *q*. crypts.

THE PHARYNX.

The **Pharynx** is a *musculo-membranous bag* that connects the mouth cavity and the esophagus. It has three coats, MUCOUS, FIBROUS and MUSCULAR.

The MUCOUS COAT is lined, in the lower, or *alimentary portion*, by *stratified squamous* cells. The upper, or *respiratory*, part is lined by *stratified ciliated* cells. These all rest upon a *basement membrane*, beneath which is the *tunica propria*, that is thrown into waves or *papillæ*. The tunica

propria contains a considerable amount of diffuse lymphoid tissue.

The FIBROUS COAT is composed of large bundles of white fibrous tissue, and serves as a support to the larger vessels and the small pharyngeal glands. It also serves as an attachment for the muscle fibres.

The MUSCULAR COAT consists of voluntary striated muscle, surrounded externally by loose areolar tissue.

The *blood-vessels* and *lymphatics* are numerous. The capillaries are found in the mucous and muscular coats, around the glands and between the muscle fibres.

ESOPHAGUS.

The remainder of the **Alimentary Tract** is *tubular*, and possesses four coats, MUCOUS, SUBMUCOUS, MUSCULAR and FIBROUS. The MUCOSA is further subdivided into four layers, *epithelium*, *basement membrane*, *tunica propria* and *muscularis mucosæ*.

In the **Esophagus,** the MUCOUS COAT is lined by *stratified sqamous* cells. These rest upon the *basement membrane*, beneath which is the *papillated tunica propria*. The *latter* consists of yellow elastic and white fibrous tissues, in which the capillary vessels form a delicate network beneath the epithelium; the ducts of the glands pass through this layer on their way to the surface. The *muscularis mucosæ* consists of involuntary, nonstriated muscle fibres, circularly and longitudinally arranged. In the upper portion of the esophagus, this layer is often wanting, but in the lower part it is always present. In the relaxed condition, the mucous and submucous coats are thrown into *longitudinal folds*.

The SUBMUCOUS COAT is composed of coarser bundles of white fibrous tissue, which forms a loose network for the

support of the large blood-vessel trunks. In this coat are seen a number of glandular structures, the *esophageal glands*, which are apparently mucous, as they stain lightly. They send their ducts through the mucous coat. As the

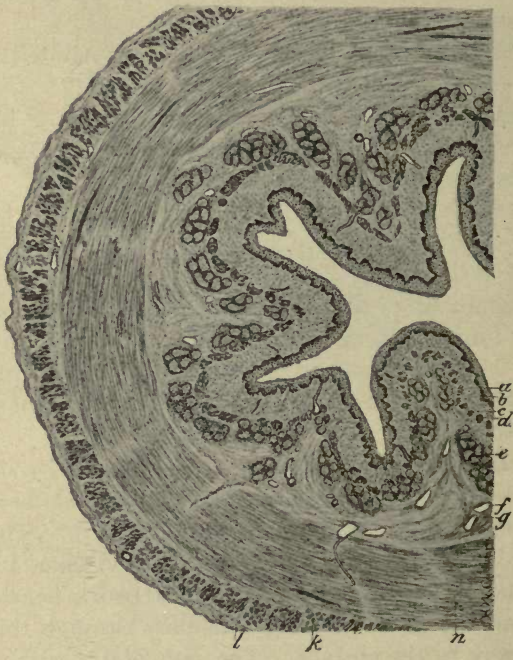


FIG. 46.—CROSS-SECTION ESOPHAGUS.

a. Stratified squamous epithelium; *b*. basement membrane; *c*. tunica propria; *d*. muscularis mucosæ; *e*. esophageal gland; *f*. blood-vessel; *g*. submucosa; *k*. outer longitudinal muscle; *l*. fibrous coat; *n*. inner circular muscle.

stomach is approached, these glands become more numerous, and may even be found in the mucosa.

The MUSCULAR COAT consists of muscle fibre, arranged in two layers, *inner circular* and *outer longitudinal*. In the

upper third, these fibres are of the *voluntary striated* variety, in the lower third, *smooth*, and in the middle portion, *mixed*. The involuntary variety continues throughout the remainder of the tract.

The FIBROUS COAT consists of fibro-elastic tissues, and connects the organ with surrounding tissues. It sends in bundles between the muscle bundles, of which they are said to form the perimysium.

The *blood-vessels* pass directly to the submucosa, where branches are formed, and sent to the mucous and muscular coats. Here they form longitudinal plexuses.

The *lymphatics* follow the same general course.

The *nerves* end in the muscular coat and beneath the epithelial cells. Others surround the glands.

STOMACH.

The **Stomach** is the first part of the tract in which the food rests for any length of time, and in which active digestion and absorption occur. Although very large, it still represents a tube, and has the four coats above mentioned. It is divided into three portions, the CARDIA, FUNDUS and PYLORIC END. They pass into one another insensibly, and the structure of the first two parts is practically the same.

The MUCOUS COAT presents a great change over that of the esophagus, showing a higher degree of specialization. In it are seen, with the naked eye, a number of minute depressions, the *gastric crypts*, or *pits*, from which the gastric glands extend into the deeper portions. Between or bounding the pits, are the *interglandular projections*. Each gland consists of *mouth*, *neck* and *fundus*, or *secretory portion*, and is lined by simple epithelial cells.

The *cells* rest upon a *basement membrane*, which, in turn,

rests upon the *tunica propria*. The latter forms the core of the interglandular projections that form the boundaries of the pits. Between the glands, the *tunica propria* consists of narrow bands of the fibrous tissue, which contains a great deal of diffuse lymphoid tissue, bundles of muscle fibres from the muscularis mucosæ, and capillaries, both vascular and lymphatic, in great numbers. In places, the lymphoid tissue is collected into solitary follicles that are lens-shaped, and are called the *lenticular follicles*, or *glands*. These are numerous in the pyloric end. The MUCOSA is bounded externally by the *muscularis mucosæ*, which consists of two layers of smooth muscle fibres, arranged as *inner circular* and *outer longitudinal bands*.

In the *cardiac* and *fundal* portions, the secretory portions of the glands are chiefly of the *simple tubular variety*. The mouth is short, with the neck and fundus of about the same length. In the *neck* and *fundus*, are found two varieties of low columnar cells, the *chief*, *peptic*, or *adelomorphous* cells, and the large *delomorphous*, *acid*, *oxyntic*, or *acid* cells.

The *peptic* cells are low columnar elements, and are found more numerous in the *fundus* than in the *neck*. The nucleus is usually circular or oval, and takes the stain very well. These cells, in the glands, have an affinity for the hematoxylin, and appear bluish when characteristically stained. They also line the *mouth* and *pits*, and cover the *interglandular projections*. In these places, the cells become very much longer, and take the stain but faintly. They form a broad band of palely stained protoplasm, in which the darkly stained nuclei have a basal location, forming a row of closely-placed bodies. The lateral boundaries are not distinct, but the nuclei indicate the breadth of the cell. Altogether, they give a feather-like appearance to the interglandular projections. Besides the peptic cells, a few *goblet* cells are found in the latter region.

The acid cells are readily distinguished from the others by their size, shape, and affinity for acid stains. They are very large, oval, or triangular elements, most numerous in the

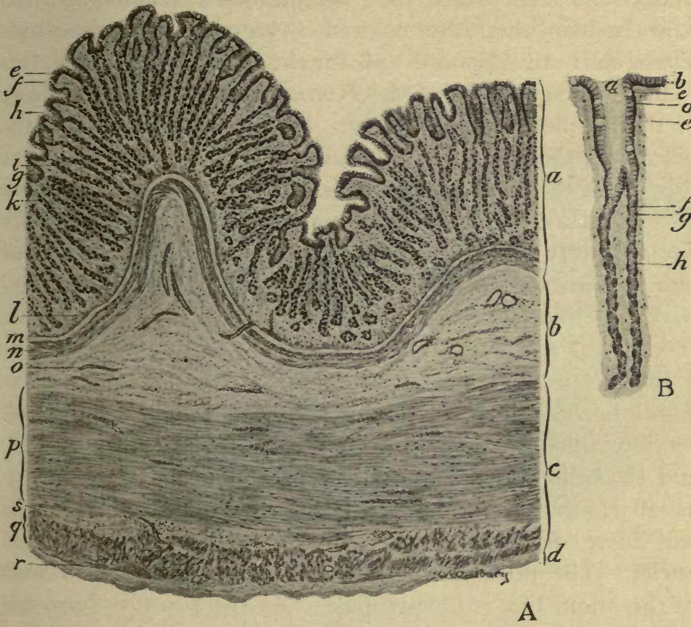


FIG. 47.—CROSS-SECTION OF SEGMENT OF STOMACH.

A. Cardiac Region—*a.* mucous coat; *b.* submucous coat; *c.* muscular coat; *d.* fibrous coat; *e.* epithelium; *f.* interglandular projection; *g.* basement membrane; *h.* gastric pit; *i.* neck of gland; *k.* acid cell; *l.* tunica propria; *m, n.* layers of muscularis mucosæ; *o.* submucosa; *p.* circular layer of muscular coat; *q.* longitudinal layer of muscular coat; *r.* oblique layer of muscular coat; *s.* white fibrous tissue layer containing the nerve plexus of Auerbach. B. Gland of Cardiac Region of Stomach—*a.* gastric pit; *b.* columnar epithelium; *c.* goblet cell; *d.* basement membrane; *e.* tunica propria of interglandular projection; *f.* neck of gland; *g.* acid cell; *h.* peptic cell.

necks, but also scattered in the *fundus*. They are found *along the wall* of the tubule, and usually beneath the peptic

cell, hence the term *parietal,* or *wall,* cell. The nucleus is quite large, and centrally located, and the protoplasm contains minute canals. The affinity for acid stains is pronounced. With eosin, they are distinctly red, while with acid fuchsin they are colored a very much deeper red. These cells are supposed to form the hydrochloric acid.

In the first portion of the FUNDUS, the glands are chiefly of the simple tubular variety. As the PYLORIC end is approached, the branched tubulars begin to increase, so that they form the predominating variety in this end. There is also a marked change in the lining cells. The acid cells become rapidly fewer in number, and, in the pyloric end, are but seldom seen. One can, therefore, be safe in saying that a section containing a number of acid cells is from the FUNDUS, or CARDIA.

In the PYLORIC END, the glands are different. The *mouth* becomes longer and wider, and the *fundus* and *neck* comparatively shorter. The *lumen* of the fundus is broader, and the cells are *only of the peptic variety.* These cells are usually *longer* and *broader* than those in the cardiac glands, and have distinct cell boundaries and prominent basal nuclei. The protoplasm, however, does not respond well to the stain, but is always pale. As the *pylorico-duodenal* junction is reached, the glands become shorter and less numerous, and some may even extend into the submucosa. The *interglandular projections* become longer, and resemble, somewhat, the VILLI of the small intestine.

The MUCOSA and SUBMUCOSA are thrown into large folds, the *rugæ.* These folds and glands increase greatly the absorptive and secretory surfaces.

The SUBMUCOUS COAT consists of loosely arranged white fibrous tissue, in which the larger blood-vessels are seen.

The MUSCULAR COAT is composed of smooth muscle arranged into three layers. Of these, the *inner* is *oblique;*

the *middle, circular,* and the *outer, longitudinal.* At both openings of the stomach, the circular fibres are more numerous, and form *sphincters.* Of these the *sphincter pylori* is the more prominent.

The FIBROUS, SEROUS or PERITONEAL COAT is composed of a thin layer of white fibrous tissue, covered by a reflection of the peritoneum.

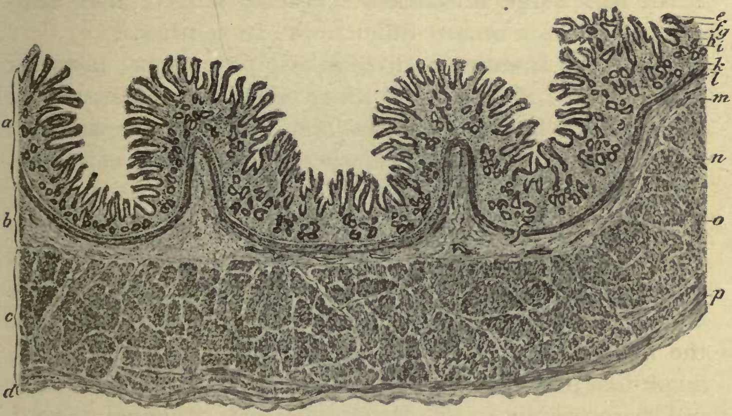


FIG. 48.—LONGITUDINAL SECTION OF SEGMENT OF PYLORIC REGION OF STOMACH.

a. Mucous coat; *b.* submucous coat; *c.* muscular coat; *d.* fibrous coat; *e.* interglandular projection; *f.* epithelium; *g.* basement membrane; *h.* gastric pit; *i.* pyloric glands; *k.* tunica propria; *l.* muscularis mucosæ; *m.* blood-vessel; *n.* connective tissue in muscular coat; *o.* inner circular layer of muscle; *p.* outer longitudinal layer of muscle.

Throughout the alimentary tract, the chief *vessels* are found in the submucosa, and from this coat, the branches are sent to the mucosa and muscularis. In the stomach, the *vascular* and *lymphatic capillaries* are very numerous in the tunica propria. The lymphatics empty into larger vessels in the submucosa, in which the veins also are formed.

The *nerves* are chiefly sympathetic, and are arranged in two plexuses, one in the submucosa, and the other in the muscular coat. (See **Intestine,** p. 146).

SMALL INTESTINE.

The **Intestinal Tract** consists of two main portions, the **Small** and **Large Intestines.** These each have their subdivisions, which usually differ from one another.

The **Small Intestine** is divided into DUODENUM, JEJUNUM and ILEUM. They all have the same general structure. This will first be described, and then the differences studied.

There are four coats, *mucosa, submucosa, muscularis* and *fibrosa,* or *serosa.*

The MUCOSA has four layers, *epithelium, basement membrane, tunica propria* and *muscularis mucosæ.* It contains a large number of *simple tubular glands,* the *crypts of Lieberkuehn,* or *intestinal crypts.* Above the level of the glands, the mucosa is thrown into an immense number of small, finger-like projections, the *villi.*

The *epithelium* is chiefly of the *simple columnar variety,* with varying numbers of *goblet* cells. Those within the gland are nearly conical in shape, and stain darkly. The protoplasm is granular, and the nucleus basal. Upon the villi, the cells are columnar, and the protoplasm granular and reticular, while the exposed margin is differentiated into a *cuticular border.* Some hold that the cells in the glands secrete a fluid used in digestion; others consider them goblet cells in different stages of secretory activity.

The *goblet* cells are distinctly columnar elements, in which the position of the nucleus varies with the state of secretion. They form the *mucin.* The protoplasm is granular and reticular, and, when *mucin* is forming, shows small clear areas; these fuse to form a single large drop of mucin that

forces the protoplasm and nucleus to the basal portion of the cell. The sides are curved, producing the goblet form. When the cuticular border ruptures, and the mucin is discharged, the cell becomes slender and irregular. These cells are found mostly upon the villi, and become more numerous as the large intestine is approached.

The *tunica propria* consists of delicate white fibrous tissue

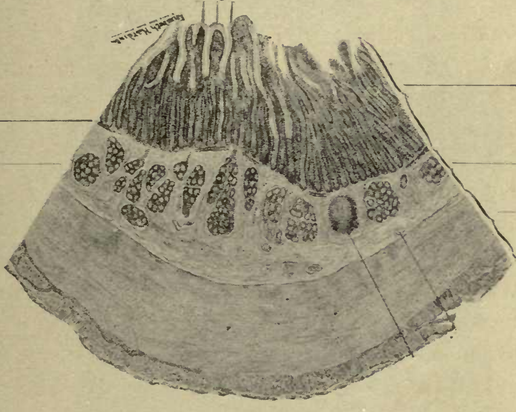


FIG. 49.—CROSS-SECTION OF DUODENUM.

1. Mucous coat; 2. submucous coat; 3. muscular coat; 4. fibrous coat; 5, 6. villi; 7. epithelium of villus; 8. muscularis mucosæ; 9. glands of Brunner.

that forms the core of the villi. It contains diffuse lymphoid tissue and capillary vessels, both lymphatic and vascular.

The *muscularis mucosæ* consists of two layers of smooth muscle fibres arranged circularly and longitudinally. From it bundles are sent up into the villi.

A VILLUS is a finger-like projection of the tunica propria, covered by a *basement membrane* and *epithelial cells* of the *simple columnar* and *goblet* varieties. The *tunica propria*

forms the core, and contains considerable diffuse lymphoid tissue, a large number of capillary blood-vessels, muscle fibres and a space in the center called the *lacteal*. It is by

FIG. 50.—LONGITUDINAL SECTION OF THE UPPER PART OF A VILLUS OF A DOG.

a. Epithelium; *b*. tunica propria; *c*. capillary; *d*. cuticular border of the epithelium; *e*. nucleus of wandering leukocyte; *f*. section of goblet cell; *g*. mucoid area of goblet cell; *h*. lacteal; *i*. smooth muscle fibre (*Stöhr's Histology*).

the villi that nature increases enormously the absorptive surface. The *lacteal* is the starting point of the lymphatic system of the intestine.

The lymphoid tissue is often collected into solitary follicles that are usually present in the mucosa, and in such areas the glands and villi are generally absent.

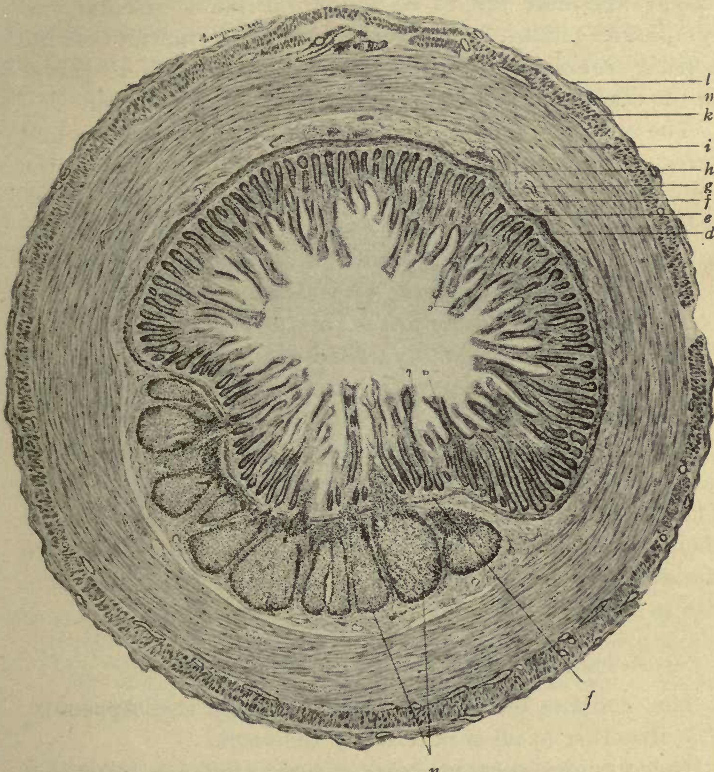


FIG. 51.—CROSS-SECTION OF ILEUM.

a. Villus; *b*. epithelium; *c*. tunica propria of villi; *d*. intestinal gland; *e* tunica propria; *f*, *f*. muscularis mucosæ; *g*. blood-vessel; *h*. submucosa; *i*. circular muscle layer; *k*. longitudinal muscle layer; *l*. peritoneal layer; *m*. fibrous coat; *n*. follicles of the Peyer's patch.

The mucosa and submucosa are thrown into circular folds. These are the *valvulæ conniventes*, or *folds of Kerk-*

ring. They are seen upon longitudinal section of the bowel.

The SUBMUCOSA consists of loose bundles of white fibrous tissue, and here are to be found the main vascular and lymphatic trunks. It enters into the formation of the *valvulæ conniventes*, and contains the *duodenal glands* of the duodenum, and the *Peyer's patches* of the ileum.

The MUSCULAR COAT is composed of *inner circular* and *outer longitudinal* layers. These are well developed in the duodenum, but become thinner as the colon is approached.

The *fibrous* coat is thin, and nearly the whole of the intestine is covered by peritoneum, forming a *serous coat.*

The JEJUNUM contains no special structures.

The ILEUM is characterized by *agminated follicles*, or *Peyer's patches.* These are collections of solitary follicles (10 to 60), generally found in both the mucosa and submucosa. Each follicle usually shows a germinal center.

The DUODENUM is characterized by the presence of a large number of *branched tubular glands* in its submucosa. The excretory ducts open at the bases of the villi, and pour their secretion into the lumen of the intestine. These are the *duodenal glands*, or *glands of Brunner*, and they give rise to the *succus entericus.*

LARGE INTESTINE.

This consists of **Cecum, Colon, Rectum** and **Appendix.** The structure of all is practically the same.

The MUCOSA contains *simple tubular glands*, *crypts of Lieberkuehn*, which are usually short, and broader than those of the small intestine. The cells lining these are *goblet* cells. The tunica propria contains a great deal of diffuse lymphoid tissue that is often collected into solitary follicles that show germinal centers. *Valvulæ conniventes and villi are absent.*

The *outer three coats* are like those of the small intestine, except for difference in the muscular coat. The longitudinal fibres are usually arranged into three bands, the *tæniæ coli*, which are about one-sixth shorter than the bowel. These act as a purse string to the intestine, and cause it to be thrown into a number of *sacculations*. If the bands be removed, the sacculations disappear.

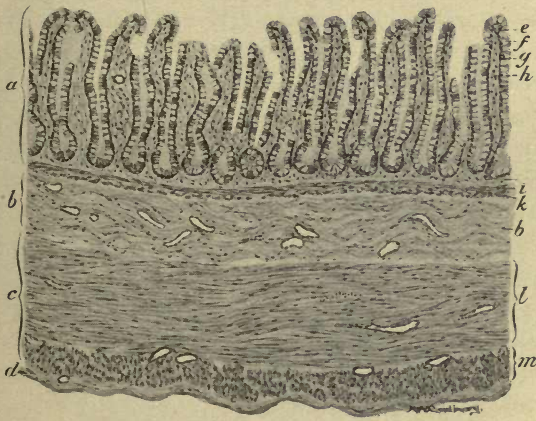


FIG. 52.—CROSS-SECTION OF SEGMENT OF COLON.

a. Mucous coat; *b.* submucous coat; *c.* muscular coat; *d.* fibrous coat; *e.* columnar cell; *f.* goblet cell; *g.* basement membrane; *h.* tunica propria; *i.* inner circular layer of muscularis mucosæ; *k.* outer longitudinal layer of muscularis mucosæ; *l.* inner circular layer of muscular coat; *m.* outer longitudinal layer of muscular coat.

The **Rectum** has its mucous and submucous coats formed into folds called the *rectal valves*. These contain a continuation of the muscular coat, by means of which the valves may be protruded into the lumen. At the lower end, the ANUS, *stratified squamous* cells replace the simple columnar, and this marks another *muco-cutaneous junction* as in the lips.

The **Appendix** is a continuation of the cecum. It has the

four coats, MUCOSA, SUBMUCOSA, MUSCULARIS and FIBROSA, or SEROSA.

The MUCOSA is usually irregular, and consists of *simple columnar* epithelial cells that rest upon a *basement membrane;* beneath the latter lies the *tunica propria*, which is bounded by the *muscularis mucosæ.*

In the MUCOSA are a large number of tube-like depressions, the *glands of Lieberkuehn.* These possess an equal diameter throughout, and are quite regularly distributed. The cells of the mucosa are the *simple columnar variety*, interspersed with many *goblet* cells. They are quite distinct, and usually possess a *basal border.* The cells in the base of the glands supply the parts higher up, and are consequently the youngest. The glands are about 25,000 (Kelly and Hurdon) in number, and are absent where the solitary follicles are found.

The *tunica propria* consists of a delicate fibro-elastic stroma containing many capillaries, considerable *diffuse lymphoid* tissue and *solitary follicles* (often 300 to 400 in number). The solitary follicles contain germinal centers, and may extend into the submucosa. Immediately over them, the glands are usually absent.

The *muscularis mucosa* is not always present. It consists of smooth muscle fibres forming a thin band separating the mucosa from the submucosa.

The SUBMUCOSA consists of loose white fibrous tissue, and supports the larger blood-vessels. In older subjects, it becomes thicker and denser, and passes into the tunica propria.

The MUSCULAR coat is usually separable into two distinct layers, *inner circular* and *outer longitudinal.* The *former* is the more prominent, and extends to the blind end, where the fibres form a dome-like collection of interlacing fibres. The longitudinal fibres are less prominent than the circular. Both layers are pierced, at intervals, by large vessels. Such

an opening, of which one especially exists at the blind end, is called an HIATUS (Kelly and Hurdon).

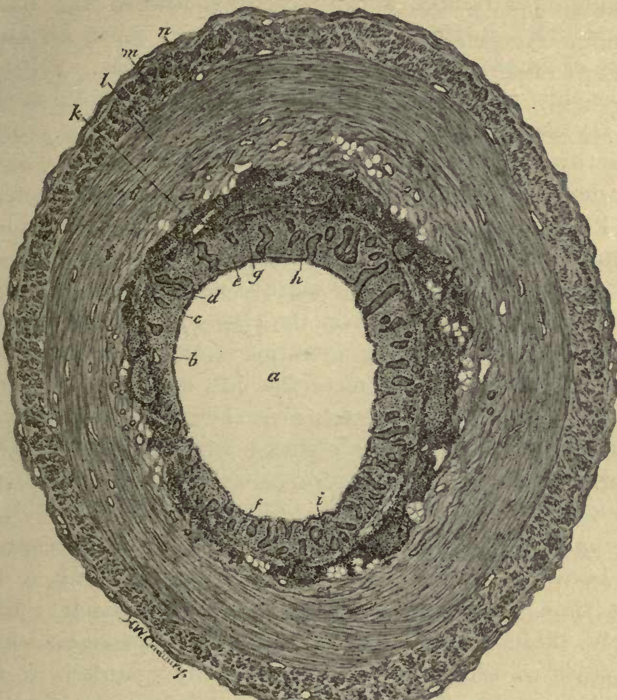


FIG. 53.—CROSS-SECTION OF HUMAN APPENDIX.
a. Lumen; *b*. epithelium; *c*. basement membrane; *d*. glands; *e*. tunica propria; *f*. diffuse lymphoid tissue; *g*. muscularis mucosæ; *h*. solitary follicle; *i*. adipose tissue; *k*. submucosa; *l*. circular muscle fibres; *m*. longitudinal muscle fibres; *n*. fibrous coat.

The SEROUS coat consists of white fibrous tissue, surrounded by the peritoneum.

The lumen tends to disappear more frequently than supposed; this change occurs during the ages ranging from 20 to 80. The older the individuals, the higher the percent-

age of occlusions. The glands are gradually destroyed by the thickening of the submucosa, this process beginning at the blind extremity and proceeding toward the bowel. Occasionally, in this process of occlusion, quite an abundance of adipose tissue is seen in the submucosa.

The chief *blood-vessels* of the intestines pass from between the layers of the mesentery into the submucosa. From these trunks, branches are sent to the various coats. In the villi, dense capillary plexuses are formed around the lacteals, and, lower down in the mucosa, around the gland. The blood is returned to the submucosa through venous channels, and these unite here to form the main venous trunks that leave the intestine to pass between the layers of the mesentery.

The *lymphatics* of the intestine start as the lacteals. These pass from the apices of the villi to the bases, where they open into a set of vessels near the muscularis mucosæ. From this plexus, vessels connect with another network in the submucosa. The latter receives lymph through other vessels that encircle the solitary follicles and patches. From this *submucous plexus*, vessels pierce the muscular coat to pass between the layers of the mesentery, receiving, at the same time, branches from the muscularis itself. Ultimately, these channels empty into the *receptaculum chyli.* The *chyle vessels*, or *lacteals*, are usually guarded, at the base, by a valve that prevents regurgitation, and aids in producing a vacuum in the lacteals, thus aiding absorption.

The *nerves* are chiefly *sympathetic* and, as in the stomach, two plexuses are formed. The *plexus of Meissner* lies in the submucosa, and that of *Auerbach* in the muscular coat, between the circular and longitudinal layers. Where the plexus fibres join, little collections of multipolar cells, called *ganglia*, are formed. The *plexus of Meissner* seems to be *a derivative of the plexus of Auerbach.* The mucosa is supplied by fibres from the former.

The cells lining the various portions of the Alimentary Tract are as follows.

LIPS		Stratified squamous.
MOUTH		Stratified squamous.
TONGUE		Stratified squamous.
PHARYNX		Stratified squamous.
ESOPHAGUS		Stratified squamous.
STOMACH	CARDIAC END	Acid cells. Peptic cells. Tall columnar. Goblet cells (a few).
	PYLORIC END	Peptic cells. Tall columnar. Goblet cells.
SMALL INTESTINE		Simple columnar. Goblet cells.
LARGE INTESTINE		Goblet cells. Simple columnar.
ANUS		Stratified squamous.

The differences between the Small and Large Intestines are as follows:

	SMALL.	LARGE.
GLANDS.	LONG AND NARROW.	BROAD.
CELLS.	CHIEFLY GLANDULAR.	CHIEFLY GOBLET.
VILLI.	PRESENT.	ABSENT.
VALVULÆ.	PRESENT.	ABSENT.
BRUNNER'S GLANDS.	PRESENT.	ABSENT.
PEYER'S PATCHES.	PRESENT.	ABSENT.
LONGITUDINAL BANDS.	ABSENT.	PRESENT.
SACCULATIONS.	ABSENT.	PRESENT.

CHAPTER X.

THE DIGESTIVE GLANDS.

The **Digestive Glands** are the **Liver,** and **Salivary Glands,** the **Parotid, Pancreas, Sublingual** and **Submaxillary.**

LIVER.

The **Liver,** the largest gland in the body, is *compound tubular* in structure. It is surrounded by a sheath of white fibrous tissue, the *capsule of Glisson*, which is covered by peritoneum. On the under surface of the organ, the capsule follows the blood-vessels at the portal or *transverse fissure* into the gland, and forms the *interlobular connective tissue.* Folds and bands form the various *ligaments, suspensory, coronary* and *lateral.* The *round ligament* is formed by the persistent, closed umbilical vein.

The **Liver** is divided into LOBES and LOBULES, of which the latter represent the UNITS. A description of a lobule will suffice for that of the whole liver.

Each **Lobule** consists of a collection of RADIATING CHAINS of HEPATIC CELLS, the TUBULES, that start from the CENTRAL, or INTRALOBULAR VEIN. These CHAINS are separated from one another by *reticulum*, which supports the cells and the INTRALOBULAR BLOOD CAPILLARIES; these capillaries are of the sinusoidal variety; that is, the endothelium is attached to the epithelium of the tubules. Each CHAIN consists of two or three cells side by side, enclosing a small capillary space called the BILE CAPILLARY. Peripherally, the lobules are not separated from one another by connective tissue, except in the *pig* and *camel.* In these animals, the lobules

are sharply outlined by bands of connective tissue. This

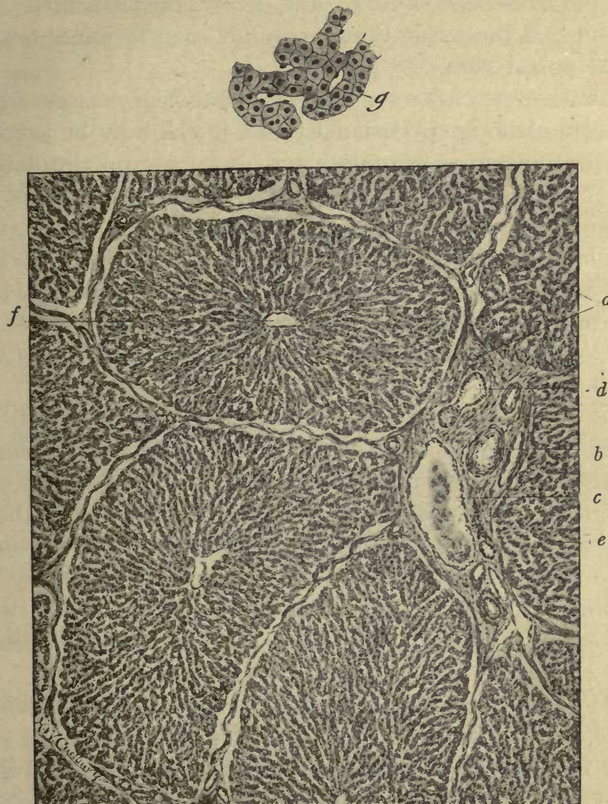


FIG. 54.—LIVER OF PIG.

a. Interlobular connective tissue containing a *portal system* consisting of
- *b*. Interlobular branch of hepatic artery.
- *c*. Interlobular branch of portal vein.
- *d*. Interlobular branch of bile duct.

e. chains of hepatic cells; *f*. central vein; *g*. chain of cells highly magnified.

occurs somewhat imperfectly in the human liver under pathologic conditions (*chronic interstitial hepatitis*).

According to Mall,* the lobule, as now considered, is not the *structural unit* of the liver; the *structural unit* refers to all the tissue that surrounds each terminal branch of the portal vein.

The HEPATIC CELLS are large, mononuclear masses of protoplasm, although occasionally two nuclei may be present. The protoplasm is granular, and may contain droplets of *fat*, *glycogen* and even *pigment granules*. The cells are traversed by minute canals, SECRETORY CAPILLARIES, that open into the bile capillaries lying between the cells. These cells are arranged in irregular chains that consist of two or three cells, in cross-section, and extend from the central vein to the periphery of the lobule. Such are the HEPATIC TUBULES.

The BILE CAPILLARIES, that lie between the cells, are merely notches in the apposed cells. They start blindly at the central vein, pass to the periphery, and empty into INTERLOBULAR VESSELS that possess a *low columnar* epithelial lining supported by basement membrane and tunica propria. These unite to form larger vessels that are lined by *tall columnar* cells. The *interlobular ducts* that lie between the lobules are lined by the same, and possess, in addition, some muscular tissue.

The INTERLOBULAR CONNECTIVE TISSUE is seen in abundance, at times, at the junction of several lobules. In such areas will be found branches of the *hepatic artery* and *vein*, *portal vein* and *bile duct*. These vessels, with the connective tissue, form a PORTAL SYSTEM, or CANAL.

The CIRCULATION of the liver is more peculiar and interesting than that of any other organ in the body. *Two* systems bring blood, yet it leaves through *one*. In other organs, the vessel that supplies the functionating tissue is an ARTERY, but here it is a VEIN, the PORTAL VEIN.

*Jour. of Anat., Vol. V, No. 3.

The PORTAL VEIN is made up of the *superior* and *inferior mesenterics*, *coronary* (stomach) and *splenic veins*. It enters *at the portal or transverse fissure* of the liver, and forms two main branches, RIGHT and LEFT, one for each main lobe. These rapidly form INTERLOBULAR BRANCHES that give rise to the INTRALOBULAR CAPILLARIES, found in the lobules, where they converge at the center and empty into the CENTRAL, OR INTRALOBULAR VEIN.

The circulation of the liver might be outlined as follows:

PORTAL VEIN.
↓
LOBAR BRANCHES.
↓
INTERLOBULAR VEINS.

Hepatic artery.
↓
Lobar branches.
↓
Interlobular arteries.
↓
Interlobular capillaries.

Most

Some

INTRALOBULAR CAPILLARIES

Central

Central vein.
↓
Sublobular vein.
↓
Interlobular vein.
↓
Hepatic veins.

The HEPATIC ARTERY enters the transverse fissure, and forms LOBAR and INTERLOBULAR branches. The *latter rapidly form capillaries that lie in the interlobular connective tissue* and nourish it, and the vessels found here. These are the INTERLOBULAR CAPILLARIES, some of which enter the outer third of the lobule and empty into the portal vein capillaries. The *remainder* of the hepatic artery capillaries empty into the interlobular branch of the portal vein, or form small venules that ultimately empty into these.

The blood that has entered the CENTRAL VEIN, from the *portal vein* and the *hepatic artery*, passes into the SUBLOBULAR VEINS, which are formed by a union of the centrals, and then into the INTERLOBULAR branches of the hepatic veins. The INTERLOBULARS are formed by a union of the SUBLOBULARS, and these, in turn, unite to form the HEPATIC VEINS that empty the blood into the *postcava*, or inferior vena cava.

As the portal vein blood comes into intimate relation with the hepatic cells, the latter remove the products required for nutrition, also the excess of glucose, which is converted into *liver sugar*, or *glycogen*, and, in addition, take out the constituents of the bile; it is now considered the seat of urea formation.

The *lymphatics* are *superficial* and *deep*. The *superficial* drain into either the celiac and hepatic lymph nodes on the one hand, or through the diaphragm into the ventral mediastinal nodes. The *deep* pass out either through the portal fissure to hepatic and celiac nodes, or along the hepatic vein pass through diaphragm to nodes around the postcava.

The blood-vessels are surrounded by lymph spaces that communicate with the capillaries and with similar spaces in the periphery of the lobule, and in the interlobular connective tissue.

The *sympathetic nerves* form the chief source of enerva-

tion of the liver. They lie in the interlobular connective tissue as plexuses, and from these some fibres pass to the bile ducts, and others penetrate the lobules to pass beneath the cells.

The **Excretory Apparatus** consists of the **Gall-bladder, Hepatic, Cystic** and **Common Ducts.** They all possess three coats, MUCOUS, MUSCULAR and FIBROUS.

In the **Gall-bladder,** the MUCOUS COAT consists of *simple columnar* cells, *basement membrane* and *tunica propria;* the *latter* is thrown into folds, in which the muscular coat also is included. In this layer, a few *mucous glands* may be found, diffuse lymphoid tissue is usually abundant, and solitary follicles are not infrequently found.

The MUSCULAR coat consists of a mixture of smooth muscle and white fibrous tissue, the *latter* predominating near the mucous coat. In the fibrous tissue are found the chief vessels that supply the other coats with branches.

The *fibrous* coat consists of white fibrous tissue, covered in part by the *peritoneum.*

The *lymphatics* are connected to those of the liver by the subserous plexus, into which the vessels from the muscular coat empty.

The *nerves* are *sympathetic* and *cerebrospinal,* the *former* passing to the blood-vessels and muscles, and the *latter* ending in the mucosa, near large arteries.

The **Ducts** have somewhat the same structure, containing a few *mucous glands* in the mucosa. The *muscle fibres* are quite distinct. They are arranged as *circular, longitudinal* and *oblique* layers. The *circular* fibres of the common duct form a *sphincter* at its entrance into the duodenum.

SALIVARY GLANDS.

The **Salivary Glands** are the **Parotid, Pancreas** (the abdominal salivary gland), **Sublingual** and **Submaxillary**

glands. In addition, there are a large number of small unnamed glands in the lips, mouth, tongue, pharynx, base of the epiglottis, and esophagus.

According to SECRETION, they are divided into MUCOUS, SEROUS and MIXED.

The MUCOUS glands are distinguished by their large *secretory units* that stain lightly. These are the *acini*, *alveoli* or *tubules*, and they give rise to a thick viscid secretion. Such glands are the small glands of the mouth, pharynx and esophagus. The SUBLINGUAL is almost a pure mucous gland.

SEROUS glands are those in which the acini stain darkly, owing to the presence of secretory granules in the protoplasm, which retain the stain. These glands secrete a thin albuminous fluid. Such are the PAROTID and PANCREAS.

The MIXED glands are those that stain both lightly and darkly, and secrete a mixed fluid, as the SUBMAXILLARY and SUBLINGUAL.

As all of these glands have the same general structure, this will be first considered, and the special points then noted.

Each is surrounded by a CAPSULE of white fibrous tissue that limits it from the surrounding organs or tissues. The CAPSULE sends in prolongations that divide the gland into LOBES and LOBULES. The LOBULES, or STRUCTURAL UNITS, consist of the *functionating units* that are composed of a single layer of *glandular epithelial cells*, supported by a *basement membrane*. External to the basement membrane, is the *interstitial*, or *intertubular connective tissue*, which is composed of *reticulum*, and in which the blood-vessels, nerves and lymphatics are found. It corresponds to the tunica propria of a mucous membrane.

The SECRETORY UNITS lead into minute INTERMEDIATE, or INTERCALATED TUBULES that unite to form INTRALOBU-

LAR DUCTS, which pass into the interlobular connective tissue. Here they unite to form the INTERLOBULAR DUCTS; these, by union, form the *lobars*, and then the SINGLE EXCRETORY DUCT. The INTERMEDIATE TUBULES are lined by *simple squamous* or *low columnar* cells, supported by basement membrane and interstitial tissue; the INTRALOBULAR branches contain *simple columnars*, the INTERLOBULARS and INTERLOBARS are lined by *pseudo-stratified columnars*, and the EXCRETORY DUCT usually by *stratified columnars*. In the latter the muscle coat is distinct.

The *blood-vessels* follow the divisions of the ducts, and form plexuses of capillaries around the units, and in close proximity to the epithelium.

The *nerves* pass down in the same manner, and, after penetrating the basement membrane, end around the cells.

The **Parotid Gland,** a *compound alveolar gland*, consists of *small, serous acini*, lined by cells adapted to fit these alveoli. The actively secreting cell has a very granular protoplasm, but that of the resting cell contains but few granules. As the granules increase, the protoplasm decreases, until expulsion of the secretion, and then the protoplasm again increases. *Secretory capillaries* exist between the cells.

This gland is not so definitely limited as the others, and, as a consequence, adipose tissue may be seen in the interlobular connective tissue, and the ductular system is said to be more highly differentiated than in any other.

The PAROTID DUCT is the excretory duct. Stenson's

The **Pancreas,** the other SEROUS GLAND, is also *compound alveolar* in structure. It is also called the *abdominal salivary gland*. The ACINI are usually distinct and sharply outlined. In these, occasionally, a small flat cell is seen occupying a central position; this is a *centro-acinar* cell, and is supposed to be one of the cells lining the intermediate tubules that extends into the acini. In addition to the acini,

certain peculiar collections of lightly-staining cells are seen. These are oval or circular in outline, and surrounded by a *capsule* of white fibrous tissue. The cells are divided into groups, each of which seems to be environed by a collection of capillaries. These are the *pancreatic islands*, or *areas, or islands of Langerhans*, and possess no outlet for the

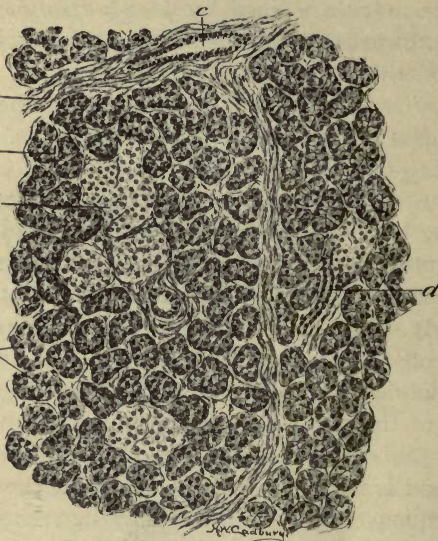


FIG. 55.—SECTION OF HUMAN PANCREAS SHOWING PANCREATIC ISLANDS.
a. Interlobular connective tissue; *b*. capillary; *c*. interlobular duct; *d*. intralobular duct; *c*. cells of acini; *f*. area of Langerhans.

secretion they are supposed to form, which is, therefore, supposed to be absorbed by the blood-vessels. Such is an *internal secretion*. These islands are considered of pathologic importance in a certain form of glycosuria.

The EXCRETORY DUCT, the DUCT OF WIRSUNG, is lined by *simple columnar* cells.

The **Sublingual,** a *tubulo-alveolar* gland, according to some is purely mucous, and differs from the above in possessing lightly-staining cells in the secretory units. These cells are large and clear during secretory activity, but smaller and cloudy after expulsion of the contents. The

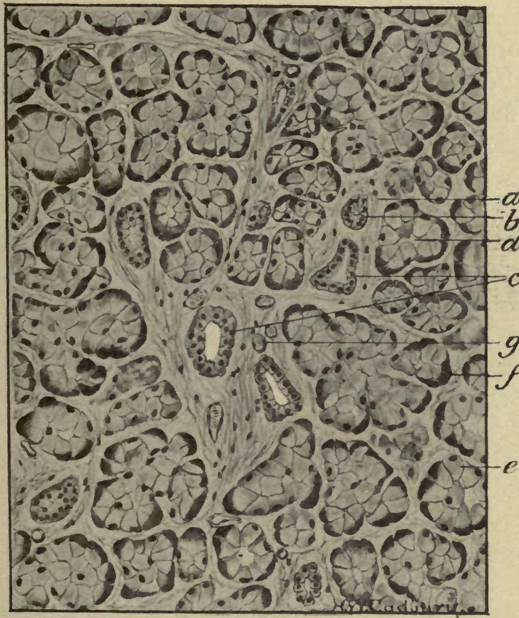


FIG. 56.—SECTION OF SUBMAXILLARY GLAND OF A FOX.
a. Connective tissue; *b*. serous acinus; *c*. intralobular ducts; *d*. lumen of a mucous acinus; *e*. mucous cells; *f*. demilune of Heidenhain; *g*. capillary.

nucleus is usually peripheral, in the former condition. Besides the above cells, there are certain darkly-staining cells or cell-groups, at the periphery of the tubules, lying between the mucous cells and the basement membrane. These are *crescent-shaped*, and are, therefore, called the

cresents of Gianuzzi, or *demilunes of Heidenhain*. According to Stöhr, they represent stages of secretory activity, in which the cells have expelled their secretion. Others hold them to be separate SEROUS cells, and that accounts for their dark stain. *Secretory canals* are said to exist in them, and this would seem to point to a serous character.

There are usually several ducts, called the SUBLINGUAL DUCTS OF DUCTS OF RIVINUS. If but one is present it is called the DUCT OF BARTHOLIN.

The **Submaxillary** is a MIXED gland in secretion, and *tubulo-alveolar* in structure. The SEROUS and MUCOUS UNITS may be separated into lobules or lobes, or may be found side by side in the same lobule. The serous are the more numerous in man. In the mucous tubules, *demilunes* are present. The ducts are unusually numerous, forming a distinguishing feature of this gland.

The *excretory duct* is the SUB-MAXILLARY DUCT, or DUCT OF WHARTON.

CHAPTER XI.

RESPIRATORY SYSTEM.

This **System** comprises the **Nares, upper part of the Pharynx,** the **Larynx, Trachea, Bronchi** and **Lungs.** Although there is no connection, the **Thyroid** and **Parathyroids** are included in this Chapter.

The **Nares** are lined by a mucous membrane, which differs according to the function of the part. The FIRST portion is lined by *stratified squamous* cells, continued from the skin surface. Here are found some large hairs, sweat and sebaceous glands. Within this area, the TRUE RESPIRATORY portion is lined by *stratified ciliated* cells, with a few *goblet* cells scattered here and there. Beneath the basement membrane, the tunica propria is represented by a delicate fibrous tissue containing some diffuse lymphoid tissue and some glands of the mucous and serous types. Above this area, the OLFACTORY MUCOUS MEMBRANE is found.

The RESPIRATORY portion of the PHARYNX, continuous with the nares, is lined by *stratified ciliated* cells. In the tunica propria, glands resembling those found in the nares are seen.

LARYNX.

The **Larynx** is a hollow, cartilaginous organ connecting the pharynx with the trachea. It consists of EPIGLOTTIS, VOCAL CORDS and LARYNX PROPER.

The EPIGLOTTIS is a projecting flap that protects the GLOTTIS during deglutition. It is covered by *stratified*

squamous cells upon both sides, and these are continuous at the edges, and rest upon *basement membrane* and *papillated tunica propria.* The *latter* is composed of fibro-elastic tissue, and contains diffuse lymphoid tissue, and, also, some glands, near its attachment. In the epithelial portion of the ventral surface, *taste-buds* are found. Beneath the tunica propria is the *submucosa,* which consists of loose white fibrous connective tissue. In it is found a plate of *elastic cartilage* that gives the stiffness, and also the elasticity, to this organ.

The VOCAL CORDS comprise the TRUE and the FALSE. The FORMER are the functionating structures, while the latter are merely heavy folds that seem to resemble the former. The TRUE CORDS alone are of importance.

The TRUE VOCAL CORDS, PLICÆ VOCALES, are covered by *stratified squamous* cells that are supported by *basement membrane* and *tunica propria.* The central portion consists of a *band of elastic tisssue.* They contain no glands.

Between the two sets of cords, there is a space, or *recess,* upon each side, called the *ventricle* of the larynx.

The *remainder* of the larynx consists of MUCOUS, SUBMUCOUS and FIBROUS coats.

The MUCOUS coat, including that of the ventricles, is lined by *stratified ciliated* epithelial cells. The *tunica propria* contains a great deal of diffuse lymphoid tissue. That portion of the SUBMUCOSA adjacent to the tunica propria possesses a number of small *mucous* glands. In its outer portion, the *cartilage masses* are found.

The form of the larynx is given by the cartilages, which are chiefly *hyalin.* Those of *Wrisberg* and *Santorini*, *middle of the thyroid* and the *apices of the arytenoids* are *elastic cartilage.*

External to the cartilage is the fibrous coat, which is composed of white fibrous tissue, supports the other coats,

and connects the larynx to the surrounding organs or tissues.

The *blood-vessels*, *nerves* and *lymphatics* are numerous. The circulatory system is represented by several networks of large vessels, and a plexus of capillaries in the tunica propria.

The *lymphatics* closely follow the blood-vessels.

The *nerves* are distributed to the mucosa, where they end near and within the epithelial layer, or in the taste-buds.

TRACHEA.

The **Trachea** connects the larynx with the lungs, its lower end bifurcating to form the **Bronchi.** It has THREE COATS, MUCOUS, SUBMUCOUS and FIBROUS.

The MUCOUS coat is a continuation of that of the larynx. It is composed chiefly of *stratified ciliated* and *goblet* cells that rest upon the *basement membrane* and *tunica propria*. The *basement membrane* is usually quite prominent, and the *tunica propria* contains considerable diffuse lymphoid tissue. It consists of fibro-elastic tissue, in which the fibres have chiefly a longitudinal direction. That portion of the mucosa opposite to the attachment to the esophagus is lined, at times, by *stratified squamous* cells, and is usually irregular.

The SUBMUCOSA is made up of white fibrous tissue, and supports the large blood-vessels and a large number of mucous glands, the *tracheal glands*. These lie in that portion near the tunica propria. In the outer part are found the *cartilage rings*.

These *so-called* rings are C-shaped masses of *hyalin cartilage*, with the open portion at the attachment of the organ to the esophagus. These masses are thickest in front, and taper as the ends are reached. Although the cartilages are

supposed to consist of one piece, they are commonly made up of a number of plates. The ends of the C's are connected by traversely and longitudinally arranged smooth

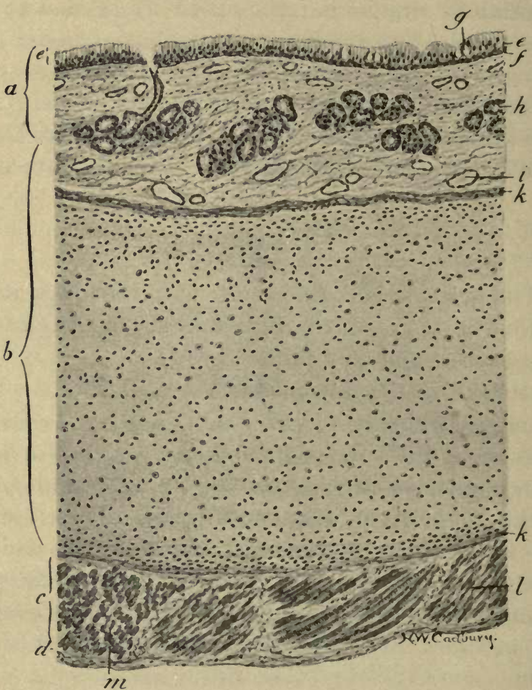


FIG. 57.—CROSS-SECTION OF SEGMENT OF THE TRACHEA.

a. Mucous coat; *b*. submucous coat; *c*, *d*. fibrous coat containing some voluntary striated muscle, *l*, *m*; *e*. stratified ciliated epithelium; *f*. basement membrane; *g*. goblet cells; *h*. mucous glands; *i*. blood-vessel; *k*. elastic tissue and perichondrium; *l*. longitudinal, and *m*, cross-sections of voluntary muscle fibres.

muscle fibres, which are attached to the inner and outer perichondriums, and then bridge the spaces between the ends of the cartilage. This strip of muscle extends the length of the trachea, but no complete muscularis is present.

The rings are sixteen to eighteen in number, and are separated from one another by white fibrous tissue.

The FIBROUS coat lies outside of the cartilage rings, and consists of white fibrous and yellow elastic tissues.

The *blood-vessels* and *lymphatics* have their larger branches in the submucosa, from which smaller vessels extend to the other coats, and form capillaries.

The *nerves* are chiefly sympathetic.

The **Bronchi** have the same general structure as the trachea. Usually the C-shaped ring of cartilage is replaced by a number of plates.

LUNGS.

The **Lungs** resemble *compound racemose glands*, the BRONCHI corresponding to the *excretory ducts*.

Each **Lung** is invested by a *fibrous sheath*, covered almost entirely by serous membrane, the VISCERAL LAYER OF THE PLEURA, which is reflected over the inside of the pleural cavity, as the *parietal layer of the pleura*. Between these two layers is the so-called *pleural cavity*, but as the lungs fill it in the living condition, it does not exist as a cavity. In it is found a small amount of lymph that lubricates the membranes.

The **Pleuræ** have the same structure as *other serous membranes*. Each consists of *endothelial cells* and *subendothelial connective tissue* that pass from the lung over to the body wall. The *subendothelial tissue* is continuous with the interlobular connective tissue of the lung.

Upon the internal surface of the lung is an area, in which the vessels and tubes enter and leave the organ; this is the ROOT of the lung, and here no serous membrane exists.

The LUNGS, like other glands, are merely systems of tubules that branch and rebranch, and are lined by different

varieties of cells. Each is an *alveolo-tubular* gland, and although no liquid secretion or excretion is formed, it plays an important part in the excretion of gases and organic matter from the blood and in the oxygenation of the blood.

The **Bronchi** divide like the ducts of any gland, and,

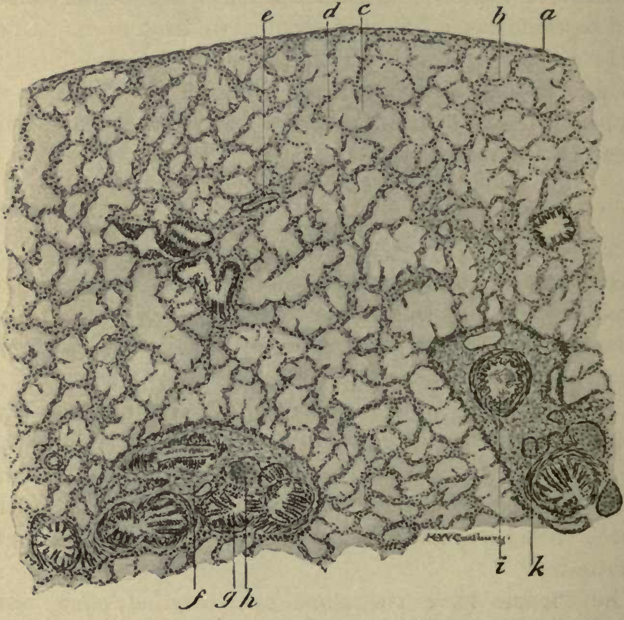


FIG. 58.—SECTION OF HUMAN LUNG.

a. Pleura; *b*. alveolar septum; *c*. alveus, or air sac; *d*. alveolus; *e*. intralobular blood-vessel; *f*. interlobular blood-vessel; *g*. interlobular bronchial tube; *h*. cartilage; *i*. branch of pulmonary artery; *k*. gland.

ultimately, the small divisions called BRONCHIOLES are reached. Each BRONCHIOLE forms a system separate and closed from its neighbors. The BRONCHIOLE (0.5 mm. in diameter) divides into the RESPIRATORY BRONCHIOLES (0.3 to 0.4 mm. in diameter); these, in turn, give rise to

ALVEOLAR DUCTS (0.2 mm.), which end as large spaces, the ALVEI, ALVEOLAR SACS or AIR SACS (0.3 by 5 mm.); along the walls of these divisions, are found small depressions the ALVEOLI, or SACCULES (0.05 to 0.1 mm.), and these are the final divisions.

A LOBULE, or STRUCTURAL UNIT, consists of the divisions of a bronchiole, and varies from 0.3 cm. to 3 cm. in diameter. It is surrounded by white fibrous tissue containing larger vessels and ducts, which are called interlobular, are over 0.5 mm. in diameter, and contain cartilage. The alvei, or air sacs, are separated from one another by yellow elastic tissue, in which a dense capillary plexus is found.

As the BRONCHUS divides and redivides, the tubules contain less and less cartilage. The first important change is the formation of a complete investment of cartilage, composed of a number of plates. As this occurs, the *muscle* tissue begins to increase, so that soon a distinct layer is seen internal to the cartilage. The lining cells are *stratified ciliated*, but the whole mucosa becomes irregular and corrugated, due to the formation of longitudinal folds; as the divisions become smaller, the cartilage diminishes. The *glands* disappear when a diameter of 1 mm. is reached. The cartilage is retained until a diameter of 0.5 mm. is attained.

Such a tubule is a BRONCHIOLE. It is lined by *simple ciliated epithelial* and *goblet* cells, supported by a *basement membrane* and an elastic *tunica propria*. External to this, the *circular muscle fibres* are quite prominent, and as a result, folds are formed. The *fibrous* tissue external contains elastic fibres, as well as vessels and nerves.

The RESPIRATORY BRONCHIOLES arise by a division of the above tubules. They are lined partially by *simple ciliated* and partially by *nonciliated* cells. The *former* are of the *simple* variety, and few in number. The *nonciliated* cells

at first are *columnar*, but quickly give way to *low cuboidal* and *flattened* cells. The last named are called *respiratory epithelium.* Along the walls of the tubules, little depressions, the *alveoli*, are seen, and here the *respiratory epithelium* is marked. Muscle fibres are found beyond the tunica propia, and elastic tissue becomes more abundant.

The ALVEOLAR DUCTS contain many alveoli lined by *respiratory epithelium*, which consists of thin, nonnucleated plates of various sizes, arranged individually or in groups. The smaller cells are derived from the cuboidal cells and are flattened by inspiration, and the larger are formed by a fusion of the smaller ones. The walls of these ducts consist of tunica propria, muscle tissue (which disappears when the end of this tubule is reached) and considerable elastic tissue circularly arranged.

The alveolar ducts lead into the ALVEUS, AIR SAC, or ALVEOLAR SAC. On the walls of this part are the small depressions, the ALVEOLI or SACCULES. These are separated from one another by minute partitions, or *septa*, that consist of *elastic tissue* covered by *simple squamous* cells, the *respiratory epithelium.* The ALVEOLI of a system communicate with one another by means of small channels, or *pores.* At the base of the alveolus, the elastic tissue is formed into a thick ring. In the meshwork of the elastica of an alveolus is found a dense plexus of blood-capillaries. The amount of elastica allows a great increase in size of the air sacs (2 to 3 times).

From W. S. Miller's careful studies on the structure of the lungs, the terminal bronchioles terminate as follows: Each *respiratory bronchiole* divides into one or more *alveolar ducts*, which widen at their outer ends. Each duct opens into several *vestibula;* from each *vestibulum*, a number of *atria* open, which, in turn, communicate with the *air sacs*, or *alvei*, on the walls of which are the *alveoli.*

The *circulatory system* is peculiar. As in the liver, *two* sets of vessels enter, the *pulmonary* and *bronchial*, but, unlike those of the liver, they do not unite to form a single system, but remain individual. There is some anastomosis between the two systems of vessels.

The *pulmonary artery* conveys the blood to be oxygenated and is the *nutrient vessel of the functionating epithelial cells.* It branches at the root, and the divisions follow those of the bronchus very closely. Between the lobules, its branches are the *interlobular divisions*, and these penetrate the lobules to form the *densest capillary plexus of the body*, within the elastica of the alveoli. Here the endothelial cells of the capillary, and the squamous epithelial cell of the alveolus, separate the blood from the air. Such an exceedingly thin membrane allows the interchange of oxygen and effete gases, and also the absorption of nutrient matter by the epithelial cells, and the outward passage of the waste matter. The blood is collected by the *venous* radicals of the *pulmonary vein*, and these unite to form the *interlobular branches*, that ultimately form the *pulmonary veins.*

The *bronchial artery* branches somewhat as the pulmonary artery, but its divisions *do not penetrate to the same degree.* They enter the lobule and form capillaries *around the vessels and ducts* here and nourish them, *but not the respiratory epithelium.* The capillaries lie in the interlobular connective tissue, and supply the vessels there with nutrient material. Between these two sets of vessels, the pulmonary and bronchial arteries, there is some anastomosis, so that the pulmonary veins carry some of the bronchial artery blood from the lungs. The bulk of the bronchial blood, however, is collected by the divisions of the bronchial veins that finally empty into the *vena azygos, right* and *left* (or *left superior intercostal*).

The *lymphatics* are *superficial* and *deep;* the former lie

beneath the pleuræ and connect with the *deep* plexus. The latter consists of vessels that follow the blood-vessels and lie in the interlobular connective tissue; these have a number of *bronchial lymph nodes* (incorrectly called *bronchial glands*) in their course.

The *nerves* are mainly sympathetic, though the vagus sends branches to the lungs. They end chiefly in the blood-vessels.

The following are the epithelial cells that line the various portions of the Respiratory Tract:

NARES	FIRST PART	Stratified squamous.
	SECOND PART	Stratified ciliated.
PHARYNX		Stratified ciliated.
LARYNX	EPIGLOTTIS	Stratified squamous.
	VOCAL CORDS	Stratified squamous.
	REMAINDER OF LARYNX	Stratified ciliated.
TRACHEA		Stratified ciliated.
BRONCHI		Stratified ciliated.
BRONCHIAL TUBES		Stratified ciliated.
BRONCHIOLES		Simple ciliated. Simple columnar. Simple squamous (respiratory).
ALVEOLAR DUCTS		Simple squamous (respiratory).
ALVEOLI		Simple squamous (respiratory).

THYROID BODY.

The **Thyroid Body** is a *ductless, compound tubular gland*, and consists of two large *lateral lobes* united by a narrow band, the *middle lobe*, or *isthmus*.

The organ is surrounded by a *capsule* that sends in trabeculæ, which divide the gland into *lobes* and *lobules*. These divisions are irregular, and the lobules are composed of a number of short *tubules*, sometimes called *follicles*. Each *tubule* is lined by *cuboidal epithelial cells* that rest upon a *basement membrane;* outside of this is the *intralobular*, or *in-*

tertubular, connective tissue that supports the blood-vessels. In the tubules is seen a peculiar, homogeneous substance, the *colloid substance*, that is supposedly the result of the activity of the cells. It has a yellowish color, and as blood-cells are frequently seen in it, the color may be due to the hemoglobin from these. Sometimes, the *colloidal material* is shrunken, and then its edges are crenated; in such tubules,

FIG. 59.—SECTION OF HUMAN THYROID GLAND.
a. Epithelium; *b*. basement membrane; *c*. colloid substance; *d*. interlobular connective tissue; *e*. interlobular vein.

the epithelial cells are drawn away from the basement membrane. Gulland and Goodall found granules of iron in the interlobular tissue cells and in the epithelial cells of the tubules. These granules were most abundant in those tubules in which the colloid substance was small in amount.

It is not unusually found that the colloid substance in the same tubule is of different reaction, most of it responding to protoplasmic stains, while a smaller amount, centrally

located and surrounded by the preceding, responds to the nuclear stain.

Blood-vessels are numerous, and dense plexuses are formed around the tubules. It is thought that the colloid material may represent an internal secretion that is absorbed by the blood-vessels, or perhaps the lymphatics.

The *lymphatics* are numerous, and lie between the tubules. *They often contain some of the colloid substance.*

PARATHYROIDS.

The **Parathyroids** are usually *four* in number, two of which lie in close relation with each lateral lobe of the THYROID. They are small, and the epithelial cells are usually of the *glandular type*, and are arranged in *groups*, or *chains*, *forming a network*, or *even tubules*. These cells respond very readily to the protoplasmic stains and are usually quite deeply stained, in marked contrast to the cells of the thyroid body. Between the cells is white fibrous connective tissue that supports quite a capillary plexus. Occasionally, *colloid material* is seen in the tubules. When the thyroids are removed and the parathyroids remain, they hypertrophy and carry on the function of the removed organs. According to some investigators, the parathyroids do not assume the function of the thyroids. Removal of the parathyroids is fatal within a short time.

CHAPTER XII.

THE URINARY SYSTEM.

The **Urinary Organs** comprise the **Kidneys, Ureters, Bladder** and **Urethra.** On account of its proximity to the kidney, the **Adrenal** will also be considered.

The **Kidney** is a *compound tubular* gland, and, next to the liver, the largest in the body. It lies in a mass of adipose tissue, the *perirenal fat*, from which it is readily separated. Some of this fat persists even when the animal dies of starvation.

The kidney is surrounded by a thin CAPSULE of white fibrous tissue that normally strips readily from the organ. This is of great importance, when the organ is studied pathologically. Beneath the capsule is the kidney PARENCHYMA that consists of a great number of tubules, the *uriniferous tubules*, that have a very irregular course. Along the internal margin is a depression or notch, the HILUS, at which the vessels enter and leave.

When the organ is sectioned, upon microscopic examination it is seen to consist of an outer margin, the **cortex,** and an inner broader portion, the **medulla.** Just within the hilus is seen a space, the SINUS, containing the PELVIS and the main branches of the renal artery and vein.

The **cortex** constitutes the outer third of the organ, and is further subdivided into MEDULLARY RAYS and LABYRINTH. This division is represented by the alternating dark and light bands, which are at right angles to the capsule, and gives a striated appearance to the cortex.

The MEDULLARY RAYS, or PYRAMIDS OF FERREIN, consist, microscopically, of the straight portions of the tubules that

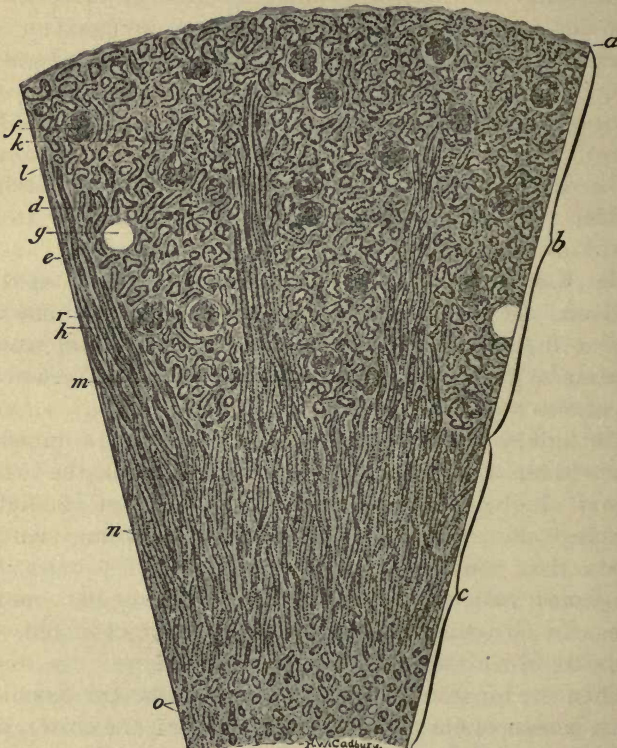


FIG. 60.—SECTION OF HUMAN KIDNEY SHOWING CORTEX AND MEDULLA.
a. Capsule; *b.* cortex; *c.* medulla; *d.* labyrinth; *e.* medullary ray; *f.* renal bodies; *g.* area in which renal body has dropped out; *h.* capsule of Bowman; *i.* glomerulus; *k.* afferent arteriole; *l.* neck of uriniferous tubule; *m.* tubules of labyrinth; *n.* longitudinal sections of collecting tubules; *o.* cross-sections of collecting tubules.

extend from the medulla into the cortex, surrounded by the intertubular, or interstitial reticulum. They never extend

to the capsule, but diminish in width as the outer portion of the cortex is approached.

The LABYRINTH lies between the medullary rays, and is composed of the MALPIGHIAN, or RENAL, CORPUSCLES, the *starting points of the tubules*, and the *convoluted portions of the uriniferous tubules*. These are supported by the *interstitial connective tissue* that contains the blood-vessels.

The RENAL CORPUSCLES are found *only in the cortex*, and here are *limited to the labyrinth*. Each one consists of a tuft *of arterial capillaries*, the GLOMERULUS, or RENAL TUFT, surrounded immediately by a delicate double membrane of *simple squamous* cells, resting upon a *basement membrane*. The *inner* layer lies upon the tuft, and the *outer* forms the wall of the tubule. This membrane is BOWMAN'S CAPSULE, and, with the tuft, comprises the RENAL CORPUSCLE. The tuft itself is not a simple structure. The arteriole, upon entering, divides into a number of branches, each of which forms a set of capillaries. This apparent lobulation is quite distinct. As these capillaries unite to form an efferent arteriole, this arrangement is called a *retia mirabilia*.

The **medulla** is sharply outlined from the cortex, microscopically, by the *absence of renal corpuscles* and the regularity of the tubules. At the junction are to be found the great vessels, and this portion is called the *boundary zone*. The **medulla** consists of the MEDULLARY, or MALPIGHIAN PYRAMIDS, separated from one another by the COLUMNS of BERTIN.

The MEDULLARY PYRAMIDS are ten to sixteen in number. Their bases continue with the cortex, and their apices are directed toward the hilus and project into the sinus. Each consists of a large number of straight tubules that become fewer in number as the apex is reached, where but fifteen to twenty are present. These are the PAPILLARY DUCTS,

OR DUCTS OF BELLINI. The tubules are supported by reticulum, in which the capillaries are found.

The PYRAMIDS are separated from one another by a narrow band of tissue, that, near the apices, is chiefly white fibrous; toward the bases, the parenchyma begins to enter into its formation. This is the *column of Bertin*, and within it are the large vessels that pass from the sinus to the boundary zone.

The PYRAMIDS represent the embryonal condition when the whole organ consisted of lobes. At birth, usually, the bases of the lobes have fused to form the cortex, but the inner ends never reach that condition. The *columns of Bertin* then represent the interlobar connective tissue and spaces. In some animals the lobulation never disappears.

The uriniferous tubule has a very peculiar and convoluted course. It starts in the cortex, and passes into the medulla, to return to the cortex for its final passage through the medulla. It originates at the RENAL CORPUSCLE, which is merely the invaginated end of the tubule, containing a tuft of capillaries. From this, the presence of a double capsule can be readily understood. The corpuscle is succeeded by a narrow constricted portion, the NECK, lined by simple squamous cells lying upon a basement membrane, and supported by interstitial connective tissue, which continues throughout. The next portion, the PROXIMAL, OR FIRST CONVOLUTED tubule, as its name indicates, is very convoluted and irregular. This part lies in the labyrinth, and is lined by cuboidal cells, in which the protopasm is granular and the cell boundaries are indistinct. That part of the cell near the lumen is striated. This continues as the DESCENDING LIMB of HENLE'S LOOP, which passes into the medulla and is succeeded by the LOOP and the ASCENDING LIMB. The descending limb and the loop, at times, are lined by simple squamous cells,

which are so flat that the nuclei project. The ascending limb, and, according to some, the loop, contains simple cuboidal cells, which may begin as flat cells. The protoplasm of these is striated. The continuation of the ascending is the SECOND, OR DISTAL, CONVOLUTED tubule, and here the cells are cuboidal and irregular, and the protoplasm granular and striated. This portion lies in the labyrinth, and is succeeded by a short, curved portion, the ARCHED CONNECTING tubule, that connects the irregular with the STRAIGHT COLLECTING tubule. These are lined by simple columnar cells that become longer as the papillæ are approached. The protoplasm of these is clear, and not striated. The STRAIGHT TUBULES, as these approach the apex of the pyramid, unite to form fifteen to eighteen large excretory tubules, the DUCTS OF BELLINI, OR PAPILLARY DUCTS. These are lined by long *columnar* cells.

The various portions of the URINIFEROUS TUBULE are distributed as follows:

Cortex. In the LABYRINTH are found the *renal corpuscles*, *neck*, *first* and *second convoluted tubules*. In the MEDULLARY RAYS, the *upper ends of the descending* and *ascending limbs of Henle's loop* and *straight collecting tubules*, and the *arched connecting tubule*.

Medulla. The *lower ends of the descending* and *ascending limbs* and *the loop of Henle* and the *straight collecting tubules* and *papillary ducts*.

The diameter of the different parts of the tubule varies. The RENAL CORPUSCLE is large, measuring 120 *to* 200 *microns*. The NECK averages about 15 *microns*, and the PROXIMAL CONVOLUTED TUBULE is quite irregular, but the average is about 40 *microns*. The DESCENDING LIMB is quite *narrow*, 10 *to* 13 *microns*, and the ASCENDING LIMB *about* 25. In the SECOND CONVOLUTED TUBULE, the diameter again increases, averaging 40 *to* 45 *microns*.

From the beginning of the STRAIGHT TUBULE to the end, the diameter progressively increases, so that the PAPILLARY DUCTS may have a diameter of 200 *microns*.

The *blood-vessels* have a characteristic distribution. The RENAL ARTERY passes through the HILUS and enters the SINUS, where it divides into a number of branches, of

FIG. 61.—SECTION OF INJECTED KIDNEY OF GUINEA-PIG.

1. Interlobular (cortical) artery; 2. afferent vessel; 3. efferent vessel; 4. capillary network in medullary ray; 5. capillary network in labyrinth; 6. interlobular (cortical) vein (*Stöhr's Histology*).

which the greater number supply the ventral pyramids, and the ventral portions of the dorsal pyramids. The branches that go to the ventral pyramids carry the greater part of this blood. The rest of the kidney is supplied by the dorsal branches. The branch that supplies each pole, derived

from the ventral division, divides into *ventral*, *middle* and *dorsal branches*, which are in no way united. The trunks pass up through the *columns of Bertin*, where small branches are given off to the vessels and tissues, as the INTERLOBAR BRANCHES. These branches pass to the *boundary zone*, where they arch between the cortex and medulla, forming the ARTERIAL ARCHES, OF ARCADE. From the cortical side of the arch, the CORTICAL, OF INTERLOBULAR, arteries are sent toward the capsule; from these, small arterioles, AFFERENT, pass to the RENAL *corpuscles*, enter and form several smaller branches, each of which breaks into a capillary tuft. From this, it will be seen that the renal tuft consists of several bunches of capillaries. Each capillary group is separate, and the vessels unite to form arterioles that leave the tuft as a single vessel, the EFFERENT arteriole. *The blood is still arterial.* The EFFERENT arterioles soon form DENSE PLEXUSES OF CAPILLARIES around the tubules of the labyrinth and medullary rays. Those capillaries near the boundary zone pass into the medulla and surround the tubules there. The CAPILLARIES become VENOUS in character, and unite with others to form the INTERLOBULAR VEINS. The CORTICAL ARTERY continues to the capsule, where it forms a star-shaped mass of venules, the VENÆ STELLATÆ. These are, in reality, the starting-points of the INTERLOBULAR VEINS, which run parallel to the arteries of the same name, and empty into a VENOUS ARCADE that is formed at the boundary zone by the union of the large vessels. Such is the blood supply of the CORTEX.

The MEDULLA receives its blood from the concave surface of the arterial arch. The arterioles given off have a straight course, and are the ARTERIOLÆ RECTÆ. They very soon break up into CAPILLARIES that surround the tubules of the medulla. These continue as VENOUS radicals that unite to

form straight veins, VENÆ RECTÆ, which empty into the VENOUS ARCH on its concave surface.

The VENOUS ARCHES unite at the columns of Bertin, and pass down these, parallel to the arteries, as the INTERLOBAR VEINS. In the sinus, they unite to form the *renal vein.*

The vessels of the kidney communicate with those of the perirenal fat, through the vessels of the capsule. This is of importance. Direct anastomoses between arterial and venous vessels occur in this organ.

The *lymphatics* comprise a *capsular set, cortical* and *medullary plexuses.* The capsular vessels empty into those of the cortical plexus. These, in turn, empty into those of the medullary plexus, the vessels of which follow the blood-vessels, emerge at the hilus, and pass to the neighboring lymph nodes.

The *nerves* are derived from both systems. They follow the vessels and envelop them in networks to the smallest divisions. Some supply the pelvis, and others pass to the tubules, and, apparently, enter the epithelium.

THE EFFERENT APPARATUS.

The **Efferent Apparatus** consists of the **Pelvis, Ureter, Bladder** and **Urethra.**

The **Pelvis** *is the upper, expanded portion of the ureter,* and lies in the sinus. It is very irregular, and is divided into two or three main portions, the INFUNDIBULA, or CALYCES MAJOR, which are arranged in little cup-like structures around the apices of medullary pyramids. These are the CALYCES MINOR, and they are equal in number to the pyramids. The three coats, MUCOUS, MUSCULAR and FIBROUS, extend throughout the ureter and bladder.

The MUCOUS membrane consists of *transitional* cells, *basement membrane* and *tunica propria.* The epithelial cells

are not all regular, as those of the transitional variety are supposed to be. The upper cells are usually somewhat flattened, and almost squamous. Beneath these, they are somewhat larger, and more or less pear-shaped, while the lowest cells are polyhedral. The *tunica propria* con-

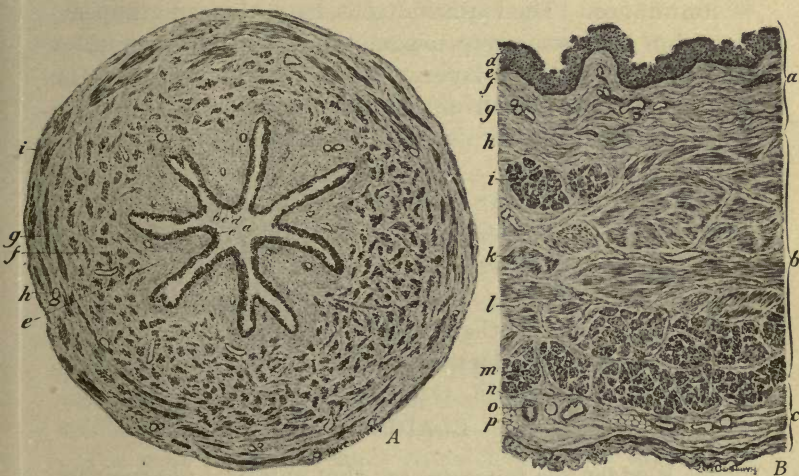


FIG. 62.

A. Cross-section of Human Ureter—*a*. lumen; *b*. epithelium; *c*. basement membrane; *d*. longitudinal fold of mucosa; *e*. tunica propria; *f*. inner longitudinal muscle; *g*. outer circular muscle; *h*. vessels; *i*. fibrous coat. B. Cross Section of Segment of Human Bladder—*a*. mucous coat; *b*. muscular coat; *c*. fibrous coat; *d*. transitional epithelium; *e*. basement membrane; *f*. tunica propria; *g*. blood-vessels; *h*. white fibrous tissue; *i*. inner longitudinal muscle; *k*. middle circular muscle; *l*. white fibrous tissue; *m*. outer longitudinal muscle; *n*. venule; *o*. arteriole; *p*. adipose tissue.

sists of delicate fibro-elastic tissue, in which lymphoid tissue may be seen.

The MUSCULAR coat consists of smooth muscle fibres that are not distinctly arranged into layers.

The FIBROUS coat is the supportive coat, and is composed of white fibrous tissue.

URETER.

The **Ureter** is the small tube connecting the kidney and the bladder, which organ it enters at an acute angle. Its coats are quite distinct.

The MUCOSA resembles that of the pelvis, with which it is continuous. The *epithelial* cells have the same appearance, but the *tunica propria* sometimes sends delicate fibres up into the epithelial layer. These fibres lie between the cells. In it are found diffuse lymphoid tissue and some racemose glands. The whole coat is usually thrown into longitudinal folds.

The MUSCULAR coat consists of smooth muscle tissue, arranged in definite layers. The *inner* consists of *longitudinal*, and the *outer* of *circular* fibres. Occasionally, at the lower end, there is added an *external longitudinal* layer, which continues into the bladder.

The FIBROUS coat does not differ from that of the pelvis.

BLADDER.

The **Bladder** is a muscular sac that acts as a reservoir for the urine. It consists of fundus or body, and a small constricted portion, the neck, which continues as the urethra.

The MUCOUS coat resembles that of the ureter in structure. The *cells* may be somewhat flatter. Often, in the ureter and bladder of children at birth, and older fetuses, the cells are all of the polyhedral type, and represent a typic layer of transitional cells. In urinary examinations, it is practically impossible to tell the cells of the pelvis, ureter and bladder from one another. The *tunica propria* contains diffuse lymphoid tissue, and even solitary follicles, also racemose glands, at times.

The mucosa is loosely attached to the muscular coat, except at a small triangular area near the neck. This space

has for its apex the urethral opening, and for its basal angle, the ureteral orifices. A line, connecting the two latter, forms the base. This area is the *trigonum vesicæ.*

The MUSCULAR coat is composed of smooth muscles. This is arranged as *inner longitudinal*, *middle circular* and *outer longitudinal* layers. All of the layers interlace, more or less, thereby giving a peculiar appearance to this coat. At the neck, the circular fibres become quite pronounced and constitute the *sphincter* of the bladder.

The FIBROUS coat supports the others, and prevents undue dilatation.

The *blood-vessels* lie in the outer portion of the tunica propria of the above organs, and from these a very close network of capillaries is formed beneath the epithelium, and in the muscular coat. These vessels are accompanied by the *lymphatics*.

The *nerves* are chiefly sympathetic, and ganglia are not uncommon. Many of the nerve fibres end beneath the epithelium.

The *male Urethra* is many times longer than that of the *female*. In the female, the structure is quite simple, and it will be first considered.

The **female Urethra** is lined by *transitional* cells, except at its outer end, where the *stratified squamous* cells of the skin enter into its structure. The transitional cells are sometimes quite flattened. Some writers describe a simple columnar layer in the middle portion. The *basement membrane* rests upon a *papillated tunica propria*, in which are found the *glands of Littré;* these, in the female, are not very numerous.

The MUSCULAR coat consists of smooth muscles, arranged as *inner longitudinal* and *outer circular* layers, separated by an intermuscular layer of white fibrous tissue.

The **male Urethra** is more complex, and is divided into

three portions, PROSTATIC, the continuation of the bladder; the MEMBRANOUS, that portion beneath the symphysis pubis, and the PENILE.

The PROSTATIC part is lined by *transitional* cells that are continued from the bladder. In the MEMBRANOUS portion, *stratified columnar* cells are present, and these become *simple* in the PENILE division. Just before the outlet, or *meatus*, is reached, the urethra dilates, and this portion is called the *fossa navicularis*. It is lined by *stratified squamous* cells. The cells are all supported by *basement membrane* and *tunica propria*, which consists of white fibrous tissue, in which the *glands* of *Littré* are very numerous.

The MUSCLE tissue is like that of the female urethra, and continues to the penile portion, where it *disappears*. In the membranous part, the muscular coat is reinforced by the *compressor urethræ* muscle, which tapers toward the prostatic and penile divisions.

The FIBROUS coat consists of white fibrous tissue, and strengthens the urethra.

Capillaries are numerous in the mucosa, and the vessels are followed by the *nerves* and *lymphatics*. The *nerves* end in the tunica propria, just beneath the epithelium.

The various portions of the Urinary System are lined by the following cells:

KIDNEY.

URINIFEROUS TUBULE:

RENAL CORPUSCLE	Simple squamous.
NECK	Simple squamous.
FIRST CONVOLUTED TUBULE .	Cuboidal to columnar.
DESCENDING LIMB	Simple squamous.
LOOP OF HENLE	Simple squamous or low cuboidal.
ASCENDING LIMB	Low cuboidal.
SECOND CONVOLUTED TUBULE	Cuboidal to columnar.

Arched Connecting Tubule	Cuboidal
Straight Collecting Tubule	Columnar
Papillary Ducts	Tall columnar.
Pelvis	Transitional.
Ureter	Transitional.
Bladder	Transitional.
Urethra. Female	Transitional. Stratified squamous.
Male	
First Part	Transitional.
Second Part	Stratified columnar.
Third Part	Simple columnar.
Fossa Navicularis	Stratified squamous.

ADRENAL.

The **Adrenal,** or **Suprarenal Body** is a *ductless gland.* It lies at the upper pole of the kidney, and has a yellow color. Upon section, it shows a yellow external layer, and a dark centrum.

The organ is surrounded by a *capsule* of white fibrous tissue, in which involuntary, nonstriated muscle may be found. Beneath this is the *parenchyma,* which consists of **Cortex** and **Medulla.**

The **Cortex** consists of three zones of epithelial cells, the ZONA GLOMERULOSA, ZONA FASCICULATA and ZONA RETICULARIS.

The ZONA GLOMERULOSA lies just beneath the capsule, and is composed of several rows of *cell-groups,* oval or circular in outline, surrounded by capillaries and reticulum. The *cells,* mostly large and polyhedral, contain a considerable number of fat globules.

Beneath this zone, the cells are arranged in columns of twos, called the ZONA FASCICULATA. These cells resemble the above, but the nuclei are on the capillary side of the cells. The columns are separated from one another by *reticulum,* supporting many capillaries.

The ZONA RETICULARIS is composed of an irregular network of cells formed by the anastomosis of the columns. These cells are usually smaller and outlines distinct. The nuclei are large, and the protoplasm pigmented.

The **Medulla** is usually separated from the cortex by a layer of large, smooth cells. Beneath this layer, the cells are arranged in irregular groups, and chains surrounded by

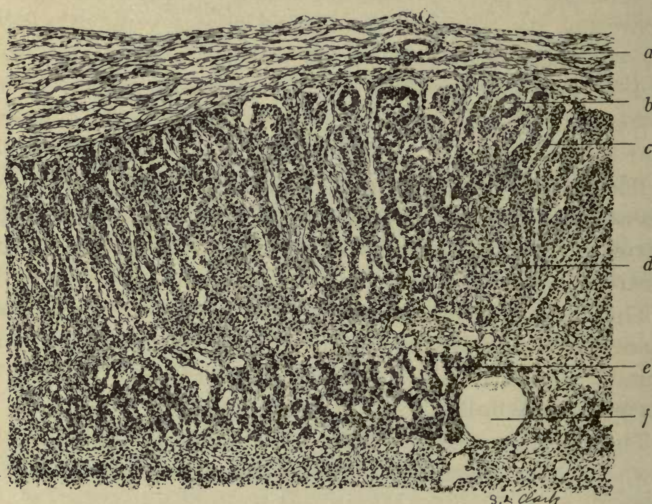


FIG. 63.—SECTION OF HUMAN ADRENAL.
a, Capsule; *b*, zona glomerulosa; *c*, zona fasciculata; *d*, zona reticularis; *e*, chromaffin cells of the medulla; *f*, medullary vein

reticulum and capillaries. These cells are small, and their outlines are indistinct. They color very deeply with chromium salts and are called chromaffin cells. These are found in other ductless glands as the hypophysis. Nerve cells are also present.

The *blood-vessels* are quite numerous, and apparently absorb the secretion of the gland. They form a plexus in the

capsule, from which the *arterial* branches penetrate the cortex, where they form many capillaries that surround the cells quite closely. These capillaries empty into thin-walled venous radicals in the outer portion of the medulla, and from them veins are formed that do not anastomose with one another, but empty into the central veins. The *medullary capillaries* are derived from the capsular vessels that pass to the medulla through the cortex without branching. They unite to form the above-named veins, which are two or four in number.

The *lymphatics* follow the blood-vessels closely. They lie between the cell-groups, and even penetrate the columns, and end between the cells.

The *nerves*, both myelinated and amyelinated, are numerous. A plexus in the capsule sends branches into the cortex, where plexuses are formed around the vessels. Branches pass from the capsular plexus to the medulla, where rich plexuses are formed around the cells and veins. *Sympathetic ganglia* are also present.

CHAPTER XIII.

THE MALE GENITAL SYSTEM.

The **Male Generative Organs** form a very complex system. They comprise the **Testicle, Epididymis, Vas Deferens, Seminal Vesicles, Ejaculatory Duct, Prostate, Glands of Cowper** and the **Penis.**

The **Testicle** is another *compound tubular* gland. It is surrounded by an unusually thick CAPSULE called the TUNICA ALBUGINEA, which is composed of bundles of white fibrous tissue that interlace so as to form a very tough and prominent covering. From its inner surface, prolongations, or *trabeculæ*, pass into the center of the organ to divide it irregularly into compartments. These trabeculæ all converge at the dorsal portion of the organ, where the capsule is very thick, forming, at this point, a thickened mass called the CORPUS HIGHMORI, OR MEDIASTINUM TESTIS. Here a number of tubules, to be described later, are found.

The TUNICA VAGINALIS TESTIS is a SEROUS MEMBRANE that, at one time, was continuous with the peritoneum. It covers almost the entire organ, and is attached to the tunica albuginea, and constitutes the *visceral layer* of the tunica vaginalis. It is reflected over the inner surface of the scrotum as the *parietal layer*. Some writers consider this membrane part of the tunica albuginea, and describe it as such, but as it is *genetically different*, it should be considered a separate covering.

The PARENCHYMA of the testicle is made up of TUBULES,

which, like those of the kidney, are very convoluted, and consist of *secretory* and *conductive* portions. These tubules are the SEMINIFEROUS TUBULES, and are collected into groups which correspond to lobules. These groups, limited by the connective tissue of the tunica albuginea

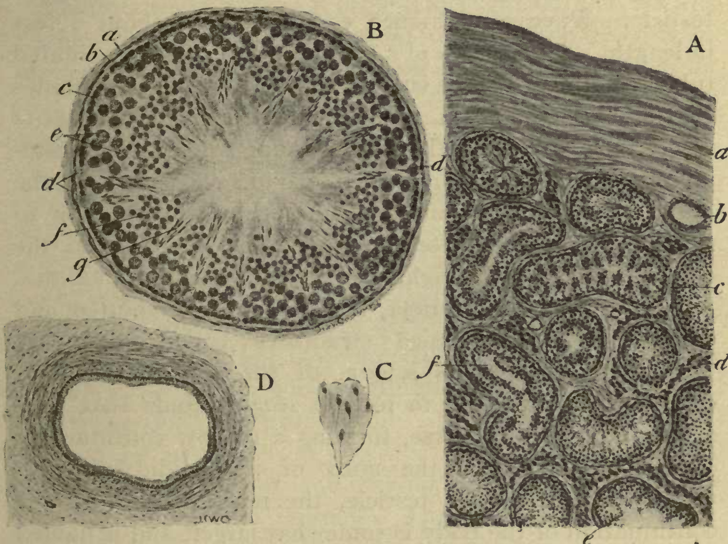


FIG. 64.—HUMAN TESTICLE.

A. Peripheral portion of the testicle showing the capsule and tubules—*a*. tunica albuginea; *b*. blood-vessel; *c*. membrana propria of tubule; *d*. interstitial cells; *e*. spermiogenetic cells; *f*. lumen of longitudinal tubule. B. Single seminiferous tubule highly magnified—*a*. tunica propria; *b*. basement membrane; *c*. spermiogonia; *d*. cells of Sertoli; *e*. mother and daughter cells; *f*. spermids; *g*. spermia. C. Spermia highly magnified. D. Tubule of the epididymis.

that extends to the *corpus*, constitute the COMPARTMENTS of the testicle.

The COMPARTMENTS contain a large number of very convoluted tubules, in which the SPERMIA are formed; these

are the SEMINIFEROUS TUBULES proper, and they are supposed to end blindly beneath the capsule. According to some, however, they anastomose, and so form a set of communicating tubules, which pass toward the apex of a compartment. There are said to be three to four convoluted tubules in each compartment, or about 600 in the testicle. When straightened each measures about 2 feet in length. At the apex of a compartment these convoluted tubules unite to form a smaller number of straight tubules that are *conductive* in function. These are the TUBULI RECTI, which pass into the mediastinum, where they anastomose to form a network called the RETE TESTIS. In the upper portion of the mediastinum, these tubules join to form a few, ten to fifteen, vessels that pass toward the edge of the corpus Highmori, as the VASA EFFERENTIA. As these leave the testicle, they become convoluted and dilated into cone-shaped structures called the CONI VASCULOSA, or GLOBUS MAJOR, of the epididymis. The CONI VASCULOSA unite to form a *single* tubule that runs a very convoluted course, forming a narrow continuation of the above, called the BODY of the epididymis. At the lower pole of the testicle, the mass formed by the continuation of the body is somewhat larger, and is named the GLOBUS MINOR. The tubule that continues from this point into the abdomen is called the VAS DEFERENS.

The SEMINIFEROUS TUBULES are from 140 to 200 microns in diameter, and form the bulk of the testicle. Each consists of a small amount of tunica propria, and a *basement membrane*, upon which is found a number of layers of cells. The basal layer consists of two varieties, the SPERMIOGONIA, which are the more numerous, and the SUSTENTACULAR CELLS, or COLUMNS OF SERTOLI.

The SPERMIOGONIA are rather large cells, in which the nuclei are mostly in the resting stage. The cells just within

these are derived from the spermiogonia, and are the MOTHER CELLS. Each mother cell divides in two *daughter cells*, which, in turn, give rise to the SPERMIDS, from which the SPERMIA are developed. These layers are not regular, as the space within the lumen is gradually filled by the reproducing cells.

The COLUMN of SERTOLI, or SUSTENTACULAR CELL is a less distinct element. It is pyramidal in shape, and extends up through the various layers, and serves as a support for the cells that are being transformed into spermia. For this reason, it has received the name of SUSTENTACULAR CELL. Its protoplasm is usually clear, though it may contain pigment granules. Its nucleus is pale, but the nucleolus is quite prominent. These cells are said to divide amitotically. It plays an important part in spermiogenesis.

Between the tubules lies the INTERSTITIAL CONNECTIVE TISSUE that supports the blood-vessels, nerves and lymphatics. It is the variety of connective tissue called *reticulum*, and here and there are found groups of large cells that contain coarse granular protoplasm. These are the INTERSTITIAL CELLS, or CELLS OF LEYDIC. The protoplasm often contains *pigment*, *fat* and *crystalloids*. These cells are probably embryonal remains. They are most numerous before and after the period of sexual activity.

The EXCRETORY SYSTEM starts with the TUBULI RECTI. These are from 25 to 50 microns in diameter, and extend to the apex of the compartment. They are lined by simple cuboidal, or squamous, cells that rest upon a basement membrane.

The RETE TESTIS consists of a network formed from the tubuli recti, and lies in the MEDIASTINUM. These tubes have a somewhat larger diameter than the foregoing, but are lined by the same variety of cells.

The VASA EFFERENTIA are few in number, and are formed

by a union of the tubules of the rete testis. The lining cells are rather peculiar in that in some areas they are simple ciliated, while in others, nonciliated. The *basement membrane* is further supported by *interstitial tissue* that contains some circularly arranged nonstriated muscle tissue.

The **Epididymis** consists of a mass of convoluted tubules that lie outside of the testicle. It is divided into three portions, the **globus major,** or **head,** the **body,** and the **globus minor,** or **tail.** The **globus major** consists of 10 to 15 large, cone-shaped tubules that are very convoluted. These tubules are the continuations of the vasa efferentia. The cilia are the largest in the body. The **body** and **tail** consist of a single long tubule that is very convoluted; if straightened it would measure 19 to 20 feet in length.

The epididymis is surrounded by a dense sheath, or capsule of white fibrous tissue that divides it into compartments. In the globus major, the tubules in a compartment represent the convolutions of one of the coni vasculosa.

The tubules are lined by STRATIFIED CILIATED CELLS that rest upon a basement membrane, outside of which is a distinct tunica propria. External to this are two layers of smooth muscle tissue, one circularly, and the other (thin) longitudinally, arranged.

The *vessels* of the testicle enter the corpus Highmori and inner layer of the tunica albuginea, and send branches around the convoluted tubules, especially, forming dense plexuses.

The *lymphatics* originate in the capsule and around the seminiferous tubules, and pass to the corpus, and leave the testicle from that point.

The *nerves* are chiefly sympathetic, but possess no ganglia. These form plexuses around the vessels and the tubules. Occasionally, ganglia are found in the epididymis.

Spermia

The **Spermatozoön**, or **Spermium**, consists of three main parts, **head, middle-piece** and **tail** (see Fig. 65).

The **head** is somewhat pear-shaped when viewed from the side and is 4 to 5 microns long and 2 to 3 microns wide. It consists of the condensed chromatin of the spermium con-

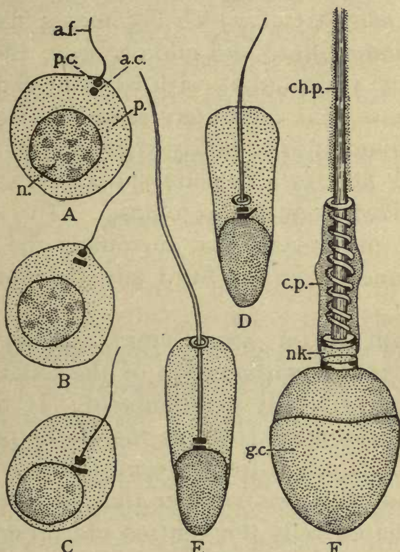


FIG 65.—DIAGRAM OF THE DEVELOPMENT OF SPERMIA (*Stöhr after Meves*).

a. c., Anterior centrosome; *a. f.*, axial filament; *c. p.*, middle piece; *ch, p.*, tail; *n*, nucleus; *nk*, neck; *p*, protoplasm; *p. c.*, posterior centrosome.

stituting 8 or 12 chromosomes. It is surrounded by a delicate layer of protoplasm. In some mammals a little body is seen at the front part of the head just beneath the enveloping protoplasm; this is the *acrosome* and it represents the attraction sphere of a centrosome. This end of the spermium represents, apparently, a cutting edge, and in

some lower forms it possesses a spiral or barbed projection that assists in the entrance of the spermium into the ovum.

The **middle-piece** is composed of several portions, the END-KNOB, AXIAL FIBRE, SPIRAL FIBRE and ENVELOP. The END-KNOB connects the head with the middle-piece and is also called the NECK. Here is seen the divided centrosome, one part of which becomes a flattened mass at the junction of head and middle-piece; the other elongates into the AXIAL FIBRE with its front end enlarged to a disc-like mass that ultimately separates from the axial fibre to surround it as a darkly staining ring. Surrounding the axial fibre is a delicate SPIRAL FILAMENT that is probably derived from the protoplasm. The ENVELOP is a thin layer of protoplasm that surrounds the middle-piece and is continued over the head and tail portions of the spermium.

The **tail** consists of AXIAL FIBRE and ENVELOP. The AXIAL FIBRE is the continuation of the axial fibre of the middle-piece, but is not so prominent. It represents an elongated centrosome. It forms the motile portion of the organism and its origin from a centrosome is not difficult to understand when we consider that in ameboid, flagellated and ciliated cells the centrosome presides over the property of motion. It is about 5 microns longer than the envelop. The ENVELOP represents a thin protoplasmic covering of the axial fibre and is continuous with that of the middle-piece. The tail is about 40 to 50 microns long and about 1 micron in diameter.

Spermiogenesis is that peculiar change by which **spermia** are formed from cells several generations removed from the **spermiogonia,** or original cells. The **spermiogonia,** with the **columns of Sertoli,** form the basal layer of cells of the seminiferous tubule. Up to the age of puberty, these tubes are usually solid, or nearly so.

The **Spermiogonia** represent the primordial cells, and by division give rise to the **mother cells,** or **spermiocytes.** These latter give rise to the **daughter cells,** and these form the **spermids,** which, by a direct change, become **spermia.** In this last division, the *chromosomes are reduced from twenty-four to twelve* (or from *sixteen to eight*). Upon fertilization, these twelve unite with the twelve within the ovum, *reduced from twenty-four* to form the twenty-four found in all cells that are derived from the segmenting ovum.

In the formation of spermia, the spermids are of the most importance. According to some authors, the nucleus forms the whole organism, while others hold the head and middle-piece are of nuclear origin, and the tail protoplasmic. These cells become crowded or drawn to the columns of Sertoli, to which they apparently attach themselves. At the same time, the shape of the cell becomes modified by elongation. The CHROMATIN of the nucleus becomes denser and migrates toward the attached, or *peripheral end*, while the protoplasm draws toward the *central end*. At the attached, or peripheral end, the nucleus has a small prominence developed that indicates the *future head*. The protoplasm becomes clear and draws centrally, forming a slender vesicle, in the middle of which a delicate line appears. This line joins the head, and, growing backward, breaks through the membrane to form the TAIL of the spermium.

The CENTROSOMES, usually two in number, become different in shape; the attraction sphere of the *smaller* passes to the head of the spermium to become the ACROSOME. The *smaller* centrosome then becomes disc-shaped and attaches itself to head at its junction with the middle-piece; the *larger* is cone-shaped, and differentiates into two portions, the *larger* of which passes toward the nucleus, and develops a flattened extremity just behind the preceding; the remain-

der elongates into the axial fibre of the middle-piece and tail. The ENVELOP is held to be protoplasmic in origin.

As the spermia continue to develop, the column of Sertoli increases in length, and when development is complete, the organisms lie in the lumen of the tubule. The column of Sertoli, with the attached spermids, is called a SPERMIOBLAST. Loisel believes that these columns secrete a substance that attracts the spermids (*positive chemiotaxis*).

The **Semen** consists principally of spermia suspended in a fluid derived from the various portions of the genital tract. The spermia are practically *amotile* until mixed with the

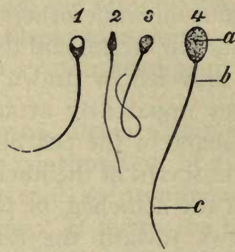


FIG. 66.—HUMAN SPERMIA.
1. Surface view; 2. side view; 3. looped seminal filament; 4. spermium of an ox; *a*. head; *b*. middle piece; *c*. tail.

secretion of the prostate, when they become actively motile. Beside the PROSTATIC FLUID, other secretion is added by the seminal vesicles, glands of Cowper and urethral glands (Littré). In addition to the spermia, *crystals* and *amyloid bodies* from the prostate, *fat globules* and *epithelial cells* are seen in the semen. There are said to be about 60,000 spermia in each cu. mm. of semen.

Motility may be exhibited by the spermia twenty-four hours after death. They have been kept alive for two weeks, under proper conditions, and this may readily occur in the female genital tract. Water, acids and metallic

salts cause cessation of action, while alkaline and normal salt solutions aid it. Batelli, in 1902, found by experiments that the spermia travel better against than with the current.

The **Vas Deferens** connects the testicle with the urethra. It passes into the body through the inguinal canal, and is accompanied, to the internal ring, by the spermatic artery and vein, the deferential artery, cremaster muscle and fibrous connective tissue. These form the SPERMATIC CORD.

THE VAS DEFERENS.

The **Vas** has three coats, MUCOUS, MUSCULAR and FIBROUS.

The MUCOUS coat consists of *stratified columnar cells* resting upon basement membrane and tunica propria. It is usually thrown into longitudinal folds. The cells in the first portion may be stratified ciliated continued from the epididymis.

The MUSCULAR coat is composed of smooth muscle tissue usually arranged as *inner* and *outer longitudinal* and *middle circular* layers. These are not always distinct, as they may interlace, more or less.

The FIBROUS coat consists of fibro-elastic tissue, and gives strength to the organ.

THE SEMINAL VESICLES.

The **Seminal Vesicles** lie beneath the bladder, and empty into the vas through the SEMINAL DUCTS. They consist of three coats, MUCOUS, MUSCULAR and FIBROUS.

The MUCOUS coat is lined by *simple columnar*, or *pseudo-stratified*, cells that possess yellow pigment granules. These cells rest upon basement membrane and tunica propria. The whole coat is thrown into waves, or folds, to which an apparent stratification of the cells is due.

The MUSCULAR coat consists of *inner circular* and *outer longitudinal* layers of the smooth variety.

The FIBROUS coat is indistinct.

These organs act as reservoirs for spermia, at times, besides secreting a fluid that helps to make up the semen.

The **Ejaculatory Ducts** are, in reality, the continuation of the vas. They are lined by *simple columnar cells*, like the seminal vesicles. The muscle tissue is chiefly *longitudinally* arranged.

THE PROSTATE.

The **Prostate** is a *branched tubular* gland. It is surrounded by a CAPSULE, and is composed of three main lobes. The CAPSULE consists, *externally*, of a thin layer of white fibrous tissue, beneath which is a thick layer of *smooth muscle tissue*. From the latter, trabeculæ pass into the center of the organ, and converge at the urethra. They possess thick bases, but taper as the center is approached. These partitions form COMPARTMENTS in which the GLANDS are found.

The GLANDS are of the *branched tubular* variety, and the ALVEOLI, OR SECRETORY, PORTIONS are lined by *simple columnar* cells, and are separated from one another by the *muscular trabeculæ*. The basal portions of the cells contain granules that have an affinity for the acid stains. The ducts are a dozen or so in number, and are lined by *simple columnar* cells, except at their outer ends, where *transitional* cells of the urethra are found. These ducts empty into the floor of the urethra. The alveoli contain a varying number of structures called *amyloid bodies;* these are few in youth and numerous in old age.

The *vessels* that supply the tubules, ramify in the muscular septa, and form plexuses of capillaries that surround the

tubules. The *veins* run toward the periphery, and form a network in the capsule.

The *lymphatics* originate in the septa, and follow the vessels.

FIG. 67.—SECTION OF THE PROSTATE GLAND.
a. Interstitial tissue and muscular trabecula; *b*. capsule; *c*. glands; *d*. prostatic bodies; *e*. secretion; *f*. blood-vessel; *g*. duct.

Nerve fibres are numerous, and some special sensor organs are present.

The **Glands of Cowper** are *racemose* glands that empty into the penile portion of the urethra. They are surrounded by a *capsule* of white fibrous tissue that divides the gland into lobes and lobules. The *alveoli* that make up a lobule

are lined by *low columnar mucous* cells. These rest upon basement membrane and tunica propria. The smaller ducts are lined by *cuboidal* cells, while the larger *possess stratified columnar* cells. Bundles of muscle fibres are present.

THE PENIS.

The **Penis** is a peculiar organ surrounded by a loosely attached skin. The latter contains *no adipose tissue.* The skin extends over the end of the organ as the PREPUCE, which is covered, upon both surfaces, by stratified squamous cells. The inner surface possesses the characteristics of a mucous membrane.

The organ consists of two main portions, the **glans** and the **body.**

The **glans** is covered by *stratified squamous* cells, and is separated from the body by a narrow constricted area, the CERVIX. At this point, the squamous cells of prepuce and glans are continuous.

The **body** consists of *two* CORPORA CAVERNOSA and the *single* CORPUS SPONGIOSUM.

The CORPORA CAVERNOSA lie side by side, forming the dorsal portion of the penis, and are bound together by a thick sheath of white fibrous tissue called the *tunica albuginea.* From the inner surface of this, *trabeculæ* pass inward and form a series of communicating spaces, or caverns. These are venous blood spaces. The trabeculæ contain tortuous arteries, the *helicine arteries*, which, when engorged, become straightened as the organ increases in size. The spaces become filled with blood, and, with the vascular trabeculæ, constitute *true erectile tissue.* This engorgement produces the erection. False erectile tissue depends for its action upon *smooth muscle tissue.*

The CORPUS SPONGIOSUM has a thin tunic, and consists of two portions, *urethral* and *peripheral*. The *urethral* part is quite dense and rich in veins, while the *peripheral* part resembles, somewhat, the cavernous portion.

The **glans** is a continuation of the corpus spongiosum, and consists of a delicate network of connective tissue enclosing a number of small spaces. It is covered by a delicate skin, which is continuous with the *prepuce*, or *foreskin*. In the cervix are located a number of glands that secrete the *smegma*. These are the *glands of Tyson*, or *glandulæ oderiferæ*.

The *blood-vessels* and spaces are numerous. The arterial branches follow the septa, in which they run such a convoluted course as to receive the name of *helicine arteries*. They form capillary plexuses in the trabeculæ, some of which empty into the spaces, while others pass over into the veins. The branches within the tunica form capillaries that empty into the spaces. Anastomoses between arterial and venous capillaries are numerous.

The *emissary veins* receive blood from the tunica and superficial vessels, and partly from the deeper tissues and vessels; they pass through the tunica to empty into the dorsal vein of the penis that lies in a groove between the corpora cavernosa. These veins are pressed upon when the superficial vessels are filled with blood, in that way preventing egress, but not ingress, of the blood.

Nerve organs include *corpuscles of Meissner*, *bulbs*, *genital corpuscles*, *Pacinian bodies* and *intra-epithelial free beginnings*.

The **Paradidymis,** or **organ of Giraldes,** is found in the epididymis. It consists of a number of tubules, in which the lining cells are low columnar or even ciliated. The tubules are closed, and are separated from one another by vascular connective tissue.

The cells that line the various portions of the male genital tract are as follows:

Testicle.

SEMINIFEROUS TUBULE	Spermiogonia Sustentacular	Basal layer.
	Spermiocytes, or mother cells. Second layer.	
	Daughter cells, Third layer.	
	Spermids, Fourth layer.	
TUBULI RECTI	Cuboidal or squamous.	
RETE TESTIS	Cuboidal or squamous.	
VASA EFFERENTIA	Columnar or ciliated.	
Epididymis	Stratified ciliated.	
Vas Deferens	Stratified columnar. Stratified ciliated (some).	
Seminal Vesicles	Simple or pseudostratified columnar.	
Ejaculatory Duct	Simple columnar.	

CHAPTER XIV.

THE FEMALE GENITAL SYSTEM.

This system consists of the **Ovary, Oviduct, Uterus, Vagina, Glands of Bartholin** and **Genitalia.**

The **Ovary,** the distinctive female organ, lies upon the dorsal surface of the broad ligament and projects into the pelvic cavity. It is surrounded by a CAPSULE of white fibrous connective tissue called the TUNICA ALBUGINEA. This is not so prominent as that of the testicle. The free surface of the capsule is covered by low columnar cells called the GERMINAL EPITHELIUM.

The organ consists of **Cortex** and **Medulla.**

The **Cortex** is the outer part, and surrounds the medulla, except at one point, at which the vessels enter and leave; this is the HILUM, and here the medulla comes to the surface. The cortex is the glandular portion, where the cellular elements of the secretion, the OVA, are formed. It consists of a delicate reticulum, the STROMA, in which the GRAAFIAN FOLLICLES are found, CORPORA LUTEA in various stages, and occasionally groups of large, polygonal epithelial cells, called the INTERSTITIAL CELLS. The free surface of the stroma is covered by the modified *mesothelial* cells, the GERMINAL EPITHELIUM, from which the ova are derived. These cells are low columnar elements.

The **Graafian follicles** are characteristic structures. They vary in size; the smallest are just beneath the tunica albuginea, the medium-sized near the medulla, and the largest extend from the medulla to the capsule, and cause a projection upon the surface of the organ.

Externally the FOLLICLE is covered by a layer of condensed stroma called the THECA FOLLICULI; the *outer* portion of this is called the TUNICA FIBROSA, and the *inner* the TUNICA VASCULOSA. The THECA is lined by a number of layers of granular cells termed the ZONA GRANULOSA, within which is

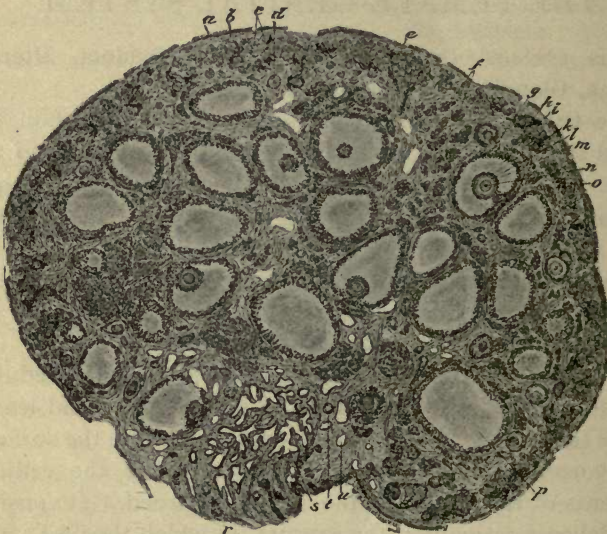


FIG. 68.—CROSS-SECTION OF OVARY OF A CAT.

The Graafian follicles are so numerous that but little of the medulla is seen. *a*. Germinal epithelium; *b*. tunica albuginea; *c*. immature Graafian follicle; *d*. ovum; *e*. cortical stroma; *f*. interstitial cells; *g*. theca folliculi; *h*. zona granulosa; *i*. antrum containing liquor folliculi; *k*. discus proligerus; *l*. corona radiata; *m*. zona pellucida; *n*. vitellus; *o*. germinal vesicle; *p*. follicle without ovum; *r*. hilum; *s*. medulla showi g the tubules of the parovarium; *t*. arteriole; *u*. venule.

a space, the ANTRUM, filled by a liquid, the LIQUOR FOLLICULI. At one point, the granule layer projects into the antrum, and this mass contains the ovum. This projection is called the DISCUS PROLIGERUS, or CUMULUS OVIGERUS. Just within the granule cells of the discus is seen a layer of

long columnar cells, the CORONA RADIATA. These cells rest upon a thick homogeneous membrane called the ZONA PELLUCIDA, which is separated from the ovum by a small space, called the PERIVITELLINE SPACE. This space is disputed by some writers. The corona is supposed to give rise to the zona pellucida. The OVUM that lies just within the space consists of a cell-wall, the VITELLINE MEMBRANE, and cell-body, the VITELLUS. In the vitellus is seen the nucleus, or GERMINAL VESICLE, which contains the prominent nucleolus, or GERMINAL SPOT.

The **Ovum** is the most characteristic and largest cell in the body. Its diameter varies from .2 to .3 mm. The zona pellucida that surrounds it is quite thick, measuring from 7 to 10 microns. It is said to contain small radial canals called *micropyles*, through which the *spermium* gains entrance to the ovum in fertilization. The protoplasm consists of yolk granules, the NUTRITIVE YOLK, or DEUTOPLASM, and the FORMATIVE YOLK. The nucleus averages about 30 microns, is eccentrically placed and sharply outlined by a membrane that possesses a double contour. The chromatin is rather scant, but the nucleolus is quite large and prominent. The centrosome may be seen in ova that have not undergone maturation. If this process has been completed the centrosome disappears. Hertwig states that they are found in ova of rabbits up to six or seven weeks of age, and in young guinea-pigs.

The Graafian follicles, of which there are about 36,000 in each ovary, are developed during intrauterine life, and all are usually present at birth. Not all of these develop, by any means. The smallest consist of the OVUM, surrounded closely by a few layers of small GRANULE CELLS and a delicate THECA. They lie just beneath the tunica albuginea, and show no antrum. The medium-sized follicles lie near the medulla, and present an antrum. The GRANULE

CELLS are more numerous, and the OVUM larger. The fully-developed follicles extend from the medulla through the cortex beyond the original surface level, projecting varying distances.

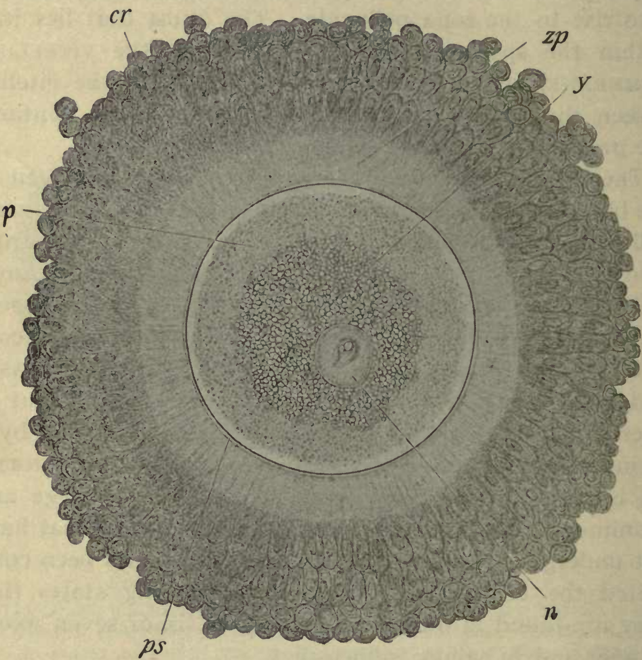


FIG. 69.—OVUM OF A WOMAN THIRTY YEARS OF AGE (*McMurrick*).
cr, Corona radiata; *zp*, zona pellucida; *p*, protoplasmic zone of ovum; *ps*, perivitelline space; *y*, yolk (deutoplasm); *n*, nucleus (germinal vesicle) showing germinal spot.

The FOLLICULAR CELLS are derived from the germinal epithelium, and grow into the stroma in long columns during the developmental period, as the EGG-TUBES OF PFLUEGER. In such a column will be found several large, and a great

number of small cells. These columns become separated into a number of groups of cells consisting of one or more large, and many small cells. The large are the OÖGENETIC, and the small the GRANULE cells. Gradually, the large cells fuse to form a single mass of protoplasm, and all the nuclei, except one, disintegrate. The single cell resulting is called the OÖCYTE. The egg-tubes are separated into these groups by the stroma that grows into the columns. This stroma further condenses around each group to form the PRIMITIVE THECA. Toward the age of puberty, these follicles begin to develop, though they may start sooner. The granule cells increase rapidly in number, and some of the more central ones disappear by disintegration or liquefaction. This gives rise to the space, or ANTRUM, which becomes filled by a liquid, the LIQUOR FOLLICULI. The latter is probably derived from the blood-vessels.

As the follicle develops and is about to rupture, the OVUM (OÖCYTE) undergoes a process called **Maturation.**

Maturation is the process by which the POLAR BODIES are formed and extruded. The germinal vesicle migrates toward the periphery, and undergoes mitotic change. When the NUCLEAR SPINDLE is formed parallel to one of the radii, the PERIPHERAL HALF, surrounded by a small amount of protoplasm, is thrust out of the cell. This is the FIRST POLAR BODY. *Without rest*, the remaining chromosomes immediately undergo division again, and the extrusion process is repeated. This is the SECOND POLAR BODY. The remaining chromosomes form a new nucleus called the GERM-NUCLEUS. By this change, the number of chromosomes is *reduced from twenty-four, in the oöcyte, to twelve, in the matured ovum.* The first polar body often divides into two, and, as a result of maturation, four cells are formed. Of these four, the ovum is the only one capable of producing an offspring. The three polar bodies disintegrate and dis-

appear. This is entirely different from the change in the testicle. In that oigan, the SPERMIOCYTE gives rise to FOUR CELLS, each of which becomes a SPERMIUM, *capable of fertilization.*

As the follicle increases in size, it approaches the tunica albuginea, and causes it to protrude. The stroma intervening between the ovum and the tunica gradually diminishes until merely the tunica albuginea remains. As the follicle increases and the pressure within becomes greater, the tunica becomes progressively thinner, until it is no longer able to withstand the pressure. Then it ruptures, and the *liquor folliculi* and the *ovum, surrounded by the granule cells*, are cast out of the ovary. The vessels of the tunica vasculosa rupture, and the follicle fills with blood. When this occurs, the body is called the CORPUS HEMORRHAGICUM. The cells of the theca penetrate the clot, and cause this to organize. In addition to these cells, there are certain other large cells that possess a yellowish pigment. These are the LUTEIN CELLS, and their function is unknown. These are derived from the theca.

If the ovum has not been fertilized, this body is called a CORPUS LUTEUM SPURIUM, which rapidly undergoes atrophy; in a few weeks, it leaves a white scar called the CORPUS ALBICANS. If fertilization has occurred, then the body persists until near the end of pregnancy, and is termed the CORPUS LUTEUM VERUM.

The CORPUS LUTEUM seems to be a gland of short duration. It seems to secrete a substance that causes the *second succeeding menstrual flow*, that is, of the next month. Experimental study upon animals, in which the follicles were destroyed, showed an almost invariable absence of the second succeeding period. The preceding flow was caused by the follicle preceding the experiment. This secretion also stimulates the uterus, and aids the implantation of the

ovum in the uterine mucosa, providing fertilization has occurred (Frankel).

Of all the follicles formed, but few are ever fertilized. A great number atrophy; in the remainder, MATURATION occurs. Of these ova, there are those which are cast into the abdominal cavity and absorbed by the peritoneum; those which pass down the genital tract and are cast out, or disintegrate, and lastly, those that become fertilized.

Ovulation includes the delivery of the ovum from the follicle and its passage through the genital apparatus. In the lower animals, in which the young are developed from eggs outside of the body (OVIPAROUS), this process is evinced by the "*laying of the egg.*" In the VIVIPAROUS ANIMALS, or those in which the offspring is developed within the mother, this process is not accompanied by any outward signs or manifestations. In the temperate climate, it begins at about the twelfth to the fifteenth year, and continues until about the forty-fifth to the fiftieth year. At this time ovulation ceases, and fertilization cannot occur thereafter.

The **Medulla** consists of a loose network formed by large, coarse bundles of white fibrous tissue, in which strands of SMOOTH MUSCLE TISSUE are found. These latter are limited to the medulla. In the meshes of the stroma are seen the INTERSTITIAL CELLS, which are more numerous than in the cortex. In this part of the ovary are found the large blood-vessel trunks which are very numerous.

The *vessels* enter the ovary at the hilus, and form a large number of branches in the medulla. From these, smaller ones are sent to the cortex, some passing to the follicles, where they form a dense surrounding plexus, while others pass to the tunica vasculosa of the tunica albuginea.

The *lymphatics* follow the vessels closely.

Nerve fibres accompany the vessels, and surround the follicles. Ganglia occur in the medulla.

The **Parovarium,** or **Epoöphoron,** lies near the hilus of the ovary, and consists of a number of short vertical tubules united to a single horizontal tube. The vertical tubules are short, and are lined by low columnar cells. The horizontal tubule has a larger diameter than the preceding, and is lined by the same variety of cells. It often lies deep in the broad ligament.

The **Paroöphoron** lies in the broad ligament, between the ovary and uterus, and consists of a number of short, closed tubules lined by low columnar cells. The tubes resemble the vertical tubes of the epoöphoron.

THE OVIDUCT.

Although the ovary possesses no excretory apparatus like other glands, the **Oviduct**, or **Fallopian Tube,** acts as such.

The **Fallopian Tube** consists of the outer FIMBRIATED END, the middle, or AMPULLA, and the inner UTERINE END, or ISTHMUS. It has three coats, MUCOUS, MUSCULAR and FIBROUS.

The MUCOUS coat consists of *simple ciliated* cells that lie upon a *basement membrane* and *tunica propria. A muscularis mucosæ is absent.* The *tunica propria* is thrown into longitudinal folds that are high in the fimbriated end, but diminish in height as the uterus is approached. These folds are the VILLI, which possess a very narrow base, but the part lying in the lumen of the tube is greatly branched. The tunica propria consists of white fibrous and yellow elastic tissues, in which diffuse lymphoid tissue is found.

The MUSCULAR coat consists of *involuntary nonstriated muscle tissue* arranged in *inner circular* and *outer longitudinal* layers. Near the uterine end, an *inner longitudinal* layer is added. This corresponds to a muscularis mucosæ.

The FIBROUS coat consists of white fibrous tissue, and is surrounded by peritoneum.

The *blood-vessels* lie in the deeper portion of the tunica propria. From these, smaller ones are sent into the villi, and into the muscular and fibrous coats. The vessels are usually quite tortuous.

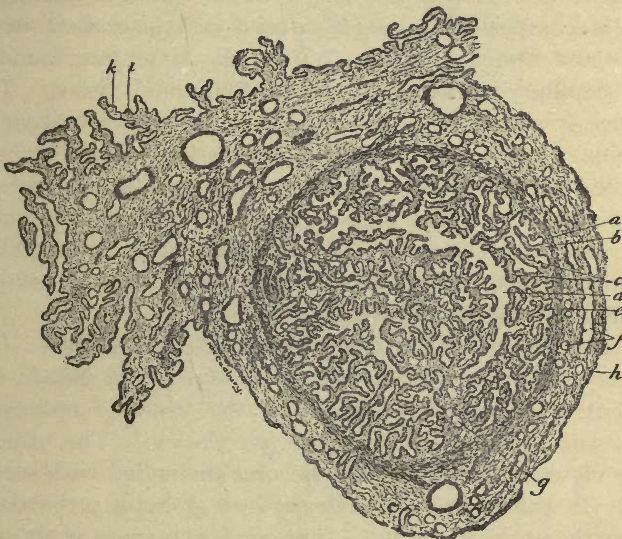


FIG. 70.—CROSS-SECTION OF THE HUMAN OVIDUCT.

a. Epithelium; *b*. tunica propria; *c*. villi; *d*. muscular coat, inner circular layer; *e*. muscular coat, outer longitudinal layer; *f*. blood-vessels in the fibrous coat; *g*. blood-vessels in villus; *h*. fibrous coat; *k*. epithelium of fimbria; *l*. tunica propria of fimbria.

The *lymphatics* accompany the blood-vessels.

The *nerves* are both myelinated and amyelinated. They accompany the blood-vessels, which they supply, and then pass to the mucosa, where they end in relation with the cells.

THE UTERUS.

The **Uterus** is a flattened, pear-shaped organ that consists of BODY and CERVIX. It is an important organ, as within it develops the offspring, in viviparous animals. All parts consist of MUCOUS, MUSCULAR and FIBROUS coats.

The MUCOUS coat of the body is about 1 mm. in thickness, and is composed of *simple ciliated cells*, *basement membrane* and *tunica propria.* Within the latter are found a rich capillary plexus and diffuse lymphoid tissue. The surface is not smooth, but is broken by the formation of GLANDS. These are tube-like depressions lined by the simple ciliated cells, and are of the *branched tubular variety.* They are the UTERINE GLANDS and extend to the muscular coat, but do not penetrate it. They are often so long that When they reach the muscular coat, they turn and extend parallel to it for some distance.

The MUCOSA of the CERVIX is a little different. The *uterine end* is lined by *simple ciliated cells*, and glands are present. The *vaginal end* is lined by *stratified squamous cells*, and *gland-like depressions are present.* The orifices often closed, causing them to become distended with secretion. In this condition, they produce globular projections called the OVULI NABOTHI. The cervical mucosa is thrown into folds called the PLICÆ PALMATÆ. The vaginal portion of the cervix is covered by stratified squamous cells.

The MUSCULAR coat consists of three layers of smooth muscle, *inner longitudinal*, *middle circular* and *outer longitudinal.* The *inner longitudinal* probably represents an *hypertrophied muscularis mucosæ.* It is separated from the middle layer by a very thin layer of connective tissue. This muscle layer is called the STRATUM MUCOSUM. The *middle layer* is the thickest, and contains the large vessels. It is called the STRATUM VASCULARE. The *outer longitudi-*

nal layer lies just beneath the fibrous coat, and is often called the STRATUM SUPRAVASCULARE.

In the CERVIX, the *circular fibres* are more pronounced, forming a dense band or ring.

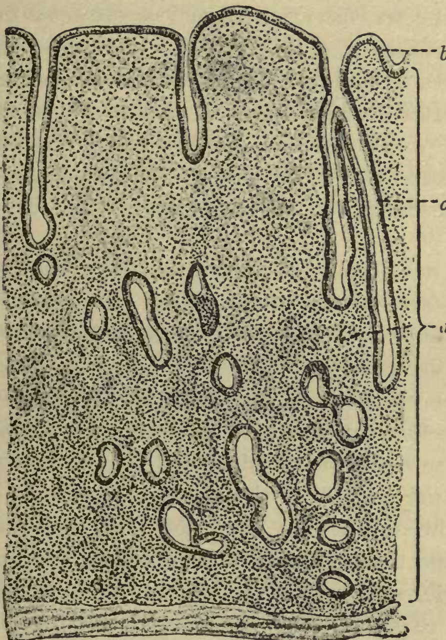


FIG. 71.—RESTING UTERINE MUCOSA.
a. Mucosa; b. epithelium; c. gland tubule (*Stöhr's Histology, after Böhm and Davidoff*).

The muscle fibres average 50 to 60 microns in length; but, during pregnancy, they lengthen to from 300 to 600 microns.

The FIBROUS, OR SEROUS, coat is quite thin. It is completely invested by peritoneum in the BODY.

Menstruation is the periodic change that occurs in the uterine mucosa, every twenty-eight days, during the child-bearing period (13th to 50th year). It is divided into stages, the HYPERTROPHIC, DESQUAMATIVE, REPARATIVE and RESTING stages.

During the HYPERTROPHIC, or CONSTRUCTIVE stage, the mucosa increases to 2 or 3 mm. in thickness, and the surface becomes irregular. This is due to the increase in size and number of the blood-vessels, and to cell proliferation in the tunica propria. The glands become broader, deeper and more tortuous. This change requires four to six days, and is succeeded by the DESQUAMATIVE, or *destructive*, stage.

The DESQUAMATIVE, or DESTRUCTIVE, stage is characterized by the appearance of the FLOW, or FLUX. It is caused by the diapedesis of some of the blood from the capillaries of the tunica propria. The blood passes into this layer beneath the epithelium, and cuts off the nutrition of the overlying cells, causing them to undergo a fatty degeneration. These cells then disintegrate, exposing the vessels, which rupture and allow the blood to pass into the uterine cavity. The surface is thus left without an epithelial covering, and the thickness of the mucosa becomes reduced. Hoppe-Seyler states that the average amount of blood lost is from 26 to 52 cu. cm. This stage, lasting three to five days, is followed by repair.

The REPARATIVE stage is that in which the mucosa returns to the normal condition. The hyperemia disappears, and the disintegrated epithelium is replaced by epithelial cells from the glands. This stage requires about five to eight days.

The RESTING stage constitutes the remaining twelve to fourteen days of the period. During this stage, the uterine mucosa is quiescent. Should fertilization occur at the time

of the constructive stage, the other three stages may not take place.

The *blood-vessels* are important. Two arteries, the uterine and ovarian, supply the organ. The main branches of these arteries pass to the middle circular layer of muscle, which plays the part of submucosa. Smaller branches are sent into the mucosa, and there form plexuses around the glands. The large trunks are very tortuous, to allow for the increase in the size of the uterus during pregnancy.

The *lymphatics* originate in the mucosa; these vessels empty into a set of larger vessels in the middle layer of the muscular coat. From here the vessels pass into the serous coat.

The *nerve fibres* are both myelinated and amyelinated. The former pass into the mucosa, some ending in the epithelial layer. The latter pass chiefly to the muscular tissue.

THE VAGINA.

The coats of the **Vagina** are the same as those of the uterus.

The MUCOUS coat consists of *stratified squamous* cells, supported by *basement membrane* and *tunica propria*. The subepithelial portion of the tunica propria is papillated. The deeper portion contains many large elastic fibres and considerable diffuse lymphoid tissue. Occasionally, some simple tubular glands are met with, and the lining cells are of the simple ciliated variety.

The MUSCULAR coat varies in thickness, that nearer the outlet being the thicker. The layers are not sharply separated from one another, but the general direction is *inner circular* and *outer longitudinal*. The mucous and muscular coats are thrown into folds that are called RUGÆ.

The FIBROUS coat consists of dense fibrous tissue, and

serves to connect the vagina with the surrounding tissues and organs.

The larger *vessels* lie in the deeper portion of the mucosa, and send branches into the mucosa and muscularis. The

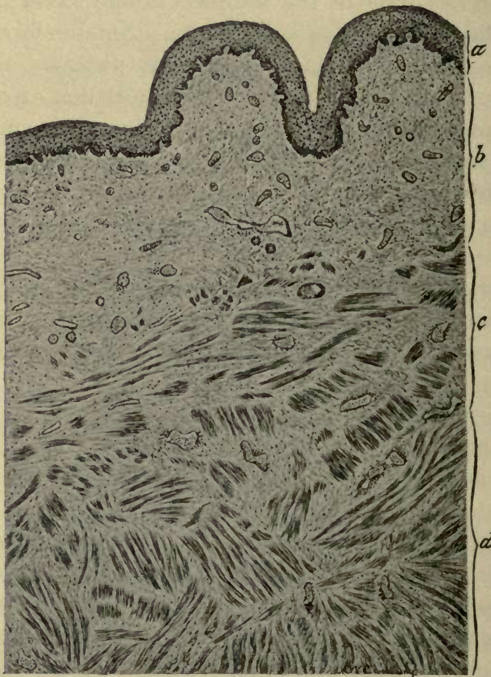


FIG. 72.—CROSS-SECTION OF SEGMENT OF HUMAN VAGINA.
a. Stratified squamous epithelium; *b*. tunica propria; *c*. inner circular muscle fibres; *d*. outer mixed muscle fibres.

capillaries of the mucosa pass chiefly to the papillæ. The veins form dense plexuses beneath the fibrous coat. Large vessels occur in the lower part of the mucosa, causing it to resemble *cavernous* tissue.

The *lymphatics* follow the same course as the blood-vessels.

The *nerves* are both myelinated and amyelinated. *Genital corpuscles* may be found in the mucosa.

THE GENITALIA.

The VAGINAL ORIFICE is guarded by a delicate annular, or crescentic membrane called the **Hymen.** This consists of white fibrous tissue covered upon its external and internal surfaces by *stratified squamous* cells. Occasionally, it is very vascular.

Just outside of this fold, the primitive uro-genital sinus spreads to form the **Vestibule** of the vagina. This is a triangular space, with the apex formed by the junction of the labia minora, the sides by these folds and the base by the vaginal orifice. It contains the opening of the urethra. This space is lined by *stratified squamous* cells. In the tunica propria, are found a great many elastic fibres and *mucous* and *sebaceous glands*, especially near the opening of the urethra. The lower portion of the tunica propria contains so many large venous channels that it is practically ERECTILE TISSUE.

Opening into the vestibule upon each side is a gland, the analog of the gland of Cowper of the male. This is the GLAND OF BARTHOLIN, which is a *compound racemose gland*, and the acini are lined by large, clear, *mucous* cells. The ducts are lined by low columnar cells.

Covering the vaginal orifice, to a greater or less extent, are seen the **Labia Minora,** or **Nymphæ.** These consist of a central mass of loose connective tissue, in which the blood-vessels are abundant, especially the veins. In the tissue between the veins, smooth muscle tissue exists, and this with the vascularity, forms to ERECTILE TISSUE. The

folds are covered upon both sides by *stratified squamous* cells that rest upon a *papillated tunica propria*. In these papillæ, capillary plexuses are seen. *Sebaceous glands are numerous*, but *hairs* and *sweat-glands are absent.*

The **Glans Clitoris** lies in the tissue formed by the junction of the labia minora. It is covered by *stratified squamous* cells. The central part consists of ERECTILE TISSUE, and many large and small vascular papillæ are present. *Genital corpuscles* and *sebaceous glands* are found. The **Glans** is covered by a fold of skin, the PREPUCE, in which the sebaceous glands are quite numerous.

The **Labia Majora** are merely folds, or pouches of skin. Their outer surfaces are covered by ordinary skin. In the subcutaneous tissue are seen numerous vessels, nerves, glands, bundles of smooth muscle and an abundance of adipose tissue. Along a median line, they come in contact with each other, and the skin surface is somewhat modified. Here elastic and muscle tissues are abundant, but adipose tissue is wanting. The skin of the labia majora is somewhat darker than that in the immediate neighborhood, due to the presence of pigment in the epithelial layers. Over the pubis, the two labia meet and form a prominent mass, the **Mons Veneris.**

The various portions of the female genital tract are lined by the following cells:

OVIDUCT	Simple ciliated.
UTERUS.	
BODY	Simple ciliated.
CERVIX, UTERINE END.	Simple ciliated.
VAGINAL END	Stratified squamous.
VAGINA	Stratified squamous.
VESTIBULE	Stratified squamous.
LABIA	Stratified squamous.

CHAPTER XV.

THE PLACENTA AND UMBILICAL CORD.

A description of the formation of the **Placenta** and **Cord** must be given in order to understand their structure at term.

Should the ovum become fertilized, it is passed down the oviduct by the ciliated cells, as fertilization usually occurs in this portion of the genital system. It is surrounded by the *zona pellucida* and *corona*, or *zona radiata*. The mucous membrane of the uterus becomes thickened, as for menstruation, and the ovum becomes lodged, usually in the fundus.

The mucosa of the uterus is divided into regions: that immediately beneath the ovum is the PLACENTAL DECIDUA, or DECIDUA SEROTINA; the ovum becomes covered by a portion called the OVULAR, or REFLEX DECIDUA; the remainder is the UTERINE DECIDUA, or DECIDUA VERA.

The ovum divides and redivides, and passes down the oviduct toward the uterus. These cells form an irregular mass, the MORULA. The outer cells of this mass arrange themselves beneath the zona pellucida as the SUBZONAL ECTODERM, or OUTER CELL MASS, while the remainder constitute the INNER CELL MASS. The entire structure grows rapidly, and, as a result, a cavity is formed around the inner mass, except at one point, where it is attached to the subzonal layer. The cavity is filled with liquid, under pressure. This mass is called the BLASTULA, or ONE-LAYERED VESICLE. The point of attachment is called the

EMBRYONIC AREA. In this condition, the ovum usually reaches the uterus.

The OUTER MASS, at the point of union with the inner mass, becomes greatly thickened, its upper portion being called the TROPHODERM (Minot), and its under portion the ectoderm. The trophoderm extends all around the zona pellucida, and is closely applied to it. The innermost cells of the INNER MASS then arrange themselves as a single layer of cuboidal cells that extend into the cavity of the blastula and form, by meeting, a little vesicle, the *entodermal vesicle*.

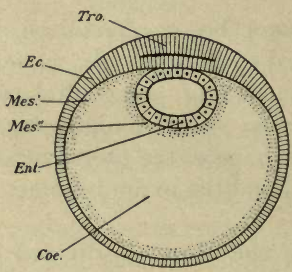


FIG. 73.—DIAGRAM OF SUPPOSED DEVELOPMENT OF PRIMATES (*Minot*). *Tro.* Trophoderm; *Ec.* ectoderm; *Mes.* mesoderm; *Ent.* entoderm; *Coe.* cœlom.

By this formation, the GASTRULA, or DIPTOBLAST, in which two distinct layers, *ectoderm* and *entoderm*, are seen, is completed. From these two layers, the *mesoderm* is derived. This constitutes the TRIPLOBLAST, or THREE-LAYERED VESICLE. The mesoderm lies between the ectoderm and entoderm, and where these layers separate, it splits into two layers, one of which accompanies the ectoderm around the triploblast to form the SOMATOPLEURE, and the other accompanies the entoderm to form the SPLANCHNOPLEURE. The mass increases in size, and the trophoderm in the embryonic area thickens greatly.

At the same time, the cells at the junction of trophoderm and ectoderm disappear, leaving a space, the AMNIOTIC CAVITY. This cavity is now bounded by trophoderm above and the combined ectoderm, mesoderm and entoderm beneath, these latter constituting the EMBRYONIC SHIELD. At the edges of the cavity, the mesoderm continues with the trophoderm, forming the PROCHORION.

At what are to be the cephalad and caudad regions of the future embryo, transverse depressions appear in the

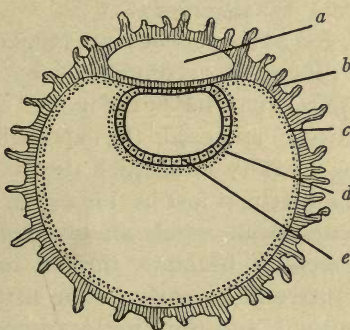


FIG. 74.—DIAGRAM OF EARLY DEVELOPMENT OF PRIMATES. Later Stage of 73 (*Minot*).

a. Aminotic cavity; *b*. ectoderm; *c* and *d*. mesoderm; *e*. entoderm.

somatopleure (one at each end); these are called the *head* and *tail folds of the amnion*, respectively. The lateral folds appear on each side in the same manner. All these grooves deepen, and the somatopleure extends ventrally from all directions (less from caudad) to form the *body-wall;* its *return folds* pass *dorsally* over the embryo to unite, forming an inner membrane next to the embryo, the *true amnion*, and an outer above the embryo, the FALSE AMNION, OR PRIMITIVE CHORION. The prochorion consists of trophoderm (ectoderm called also the *placentoblast*) and mesoderm; the amnion, of mesoderm and ectoderm, and the body-wall of

ectoderm and mesoderm, respectively. At all points, like layers are opposed to like layers. In the formation of the body-wall and amnion, the SPLANCHNOPLEURE has been pushed before the somatopleure to form a tube within the body, the GUT-TRACT and a sac outside, the YOLK SAC and VITELLINE DUCT.

In the formation of the amnion, the embryo loses its connection with the chorion at all points, except caudally, where the mesoderm and ectoderm of the two are continuous, forming the BELLY-STALK.

By this time, the ovum has become lodged in the uterine mucosa. This process is accomplished by the aid of the trophodermal cells, that have the power of *phagocytosis* (destruction of tissue) and erode the superficial tissues of the mucosa, forming a cavity into which the ovum sinks. The epithelium of the uterus is lost in this region and also in the glands and the superficial vessels are exposed. The trophoderm, or *placentoblast* becomes thrown into little processes, or *villi* (present as early as the fifth day, Peters), due to actual growth and the disappearance of cells in the trophoderma' layer. As a result, there are formed a series of intercommunicating spaces, the *trophodermal lacunæ.* The villi are composed of trophoderm and mesoderm. When the vessels of the mucosa are exposed, they rupture into the glandular spaces, and from these, the maternal blood gains access to the *trophodermal lacunæ*, or *spaces*. Thus does the embryo receive nourishment from the mother, before the umbilical vessels are present. The area of the ovum left uncovered when the ovum becomes lodged, is covered by mucosa that is reflected from the lining at the sides of the ovum. This is, therefore, called DECIDUA REFLEXA, or OVULAR DECIDUA.

We must remember that the BELLY-STALK connects the embryo with the prochorion. This belly-stalk is of

importance, because it represents that part of the embryonic disc that does not lose connection with the prochorion during the formation of the body-wall and gut-tract. Into the belly-stalk the allantoic evagination of the gut-tract extends for a short distance, while the allantoic vessels pass along the entire extent of the stalk to the forming chorion. With the passage of the allantoic vessels

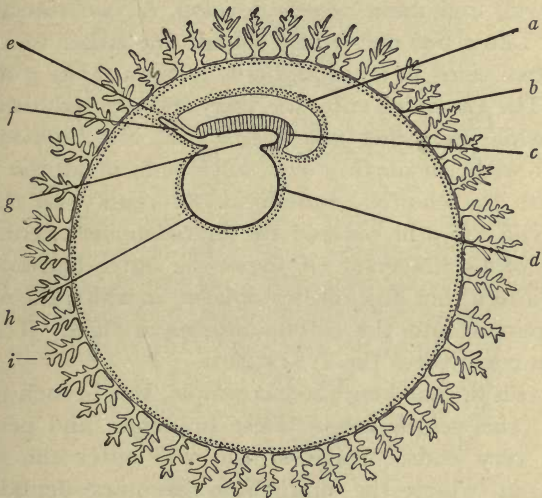


FIG. 75.—DIAGRAM OF EARLY DEVELOPMENT OF PRIMATES. Later than FIG. 74. (*Minot*).

a. Amnion; *b*. chorion; *c*. embryo; *d*. yolk-sac; *e*. body-stalk; *f*. allantois; *g*. entodermal cavity of embryo; *h*. entoderm; *i*. chorionic villi.

to *vascularize the chorion*, the *belly-stalk becomes the so-called extra-embryonic portion of the allantois*. In some animals, the OVIPAROUS, the allantois *loses connection with the belly-stalk*, and is free. It remains as a dilated sac, and serves as a receptacle for urine. In the *viviparous* animals, it *remains connected with the belly-stalk, and is said to connect the embryo with the uterus*, becoming the

organ of nutrition and respiration. As a matter of fact, it seems to be the belly-stalk that forms the link between fetus and chorion; the chorion becomes the fetal portion of the placenta, while the belly-stalk becomes the umbilical cord by the addition of the vessels. It would seem that the allantois proper has nothing to do with the formation of the placenta and cord in the higher types. In this mesoderm, four main vessels develop, *two arteries* and *two veins.* Later but one vein is found, due either to a fusion of the two veins, or more probably to the *atrophy of the right vein.* The two veins enter the body and proceed toward the heart, while the other two vessels pass into the body, and connect with the aorta. The distal ends of all the vessels pass into the chorion, and divide to ramify all the villi. These villi are still covered by the trophoderm, consisting usually of two layers. Of these, the outer becomes converted into a thin layer of protoplasm, in which the original nuclei remain and the cell-boundaries are lost. This protoplasm constitutes the SYNCYTIUM.

The villi do not long remain simple, but branch and rebranch; the vessels follow these branches, and penetrate to the very ends. Some of the villi enter the uterine glands, in which the epithelium becomes denuded by about the sixth week, and the surface cells by the fourth week, and are the *floating villi;* others become attached, and form the *fixed villi.* When the epithelium of the uterus is lost, the engorged superficial capillaries of the placental decidua become connected with the glands, and the blood enters these, and then the trophodermal spaces. These channels are the later *intervillous spaces.* From these cavities, the blood is returned to the venous channels of the mucosa, but no *direct connection is established between the fetus and the mother.*

These villi are very abundant, and may be scattered all

over the ovum or be limited to the equator of the mass. Up to this time, all are equal in size. Soon a difference is noted in size, those at the place of attachment of the ovum increase in number and size, forming the *chorion frondosum*,

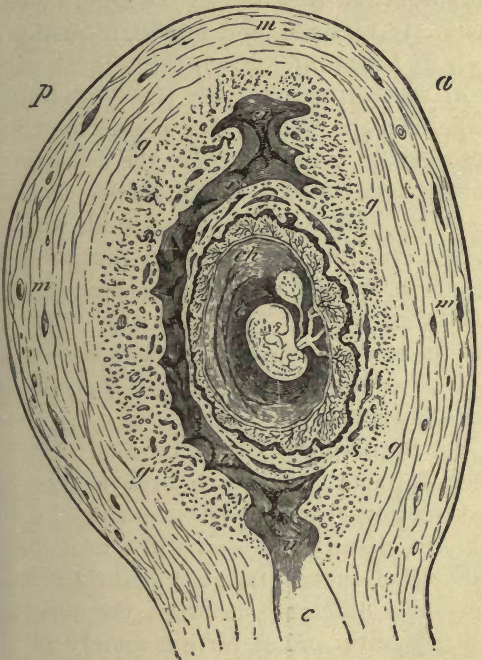


FIG. 76.—SEMI-DIAGRAMMATIC OUTLINE OF A DORSO-VENTRAL SECTION OF A HUMAN UTERUS CONTAINJNG AN EMBRYO OF ABOUT FIVE WEEKS.

a. Ventral, *p*. dorsal surface; *g*. outer limit of decidua; *s*, *s*. limits of the placental decidua; *ch*. chorion, within which is the embryo enclosed by the amnion, and attached to the chorion by the umbilical cord; from the cord hangs the pedunculated yolk-sac; *r*, *r*. ovular decidua (*Minot*).

while the remainder disappear and constitute the *chorion læve*. The latter do not become vascularized.

At about the fifth month, a villus has the following appearance. Of the trophodermal cells, the outer do not re-

main large, distinct elements, but become flattened, and represent a mere layer of nucleated protoplasm that covers the villi; this is the *syncytium*, and it is the covering of the embryonic connective tissue that constitutes the core of the villi and supports the vessels. In the inner layer, the cells remain distinctly outlined, and persist for a short time as the *cell-layer of Langhans*. From the fifth month on, they disappear so that ultimately only the syncytium remains. Here and there on the villi are seen groups of cells that represent collections of syncytial cells, the *cell knots*. These, like the other syncytium, contain nuclei that are small, but stain deeply. The protoplasm responds well to the acid stains. The Langhans cells, however, contain large nuclei, but neither these nor the protoplasm respond well to stains.

After the third month, the number of villi that become attached to the mucosa rapidly increases, so that after that time the fetal and maternal portions become more and more fixed to each other.

This is the beginning of the formation of the placenta as it is seen at birth. The villi branch repeatedly, and the whole structure grows rapidly, causing the child to do the same. Any disturbance that will retard the growth of the placenta will also retard the growth of the fetus in greater proportion. The difference between the placenta at the fourth or fifth month and at birth is merely in size. This is due to the increase in number and branches of the villi. The villi are separated into groups by connective-tissue septa that are derived from the uterine tunica propria. These are the *placental septæ*.

At birth the **Placenta** is a flesh-like, saucer-shaped mass, the attached surface of which is divided into lobes, or *cotyledons*. The fetal surface is covered by the amnion, a continuation of the sac in which the fetus lies, and shows the vessels as they enter and leave the organ; the opposite

surface is divided into lobes, or cotyledons, covered by the decidua serotina. The weight of the placenta is about

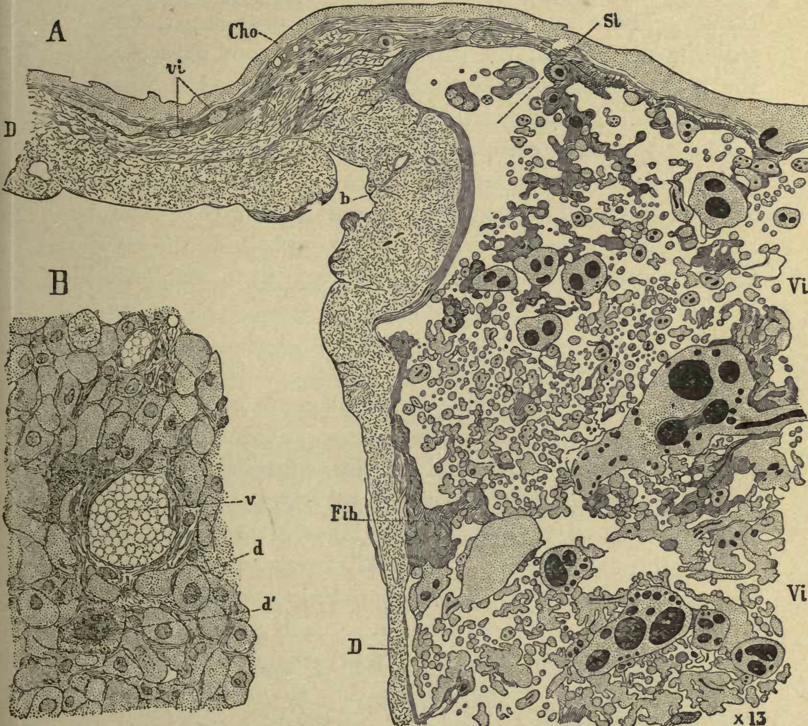


FIG. 77.—HUMAN PLACENTA AT TERM.

A. Vertical section at margin; D. decidua; *Cho.* chorion; *Fib.* fibrin; *Vi.* placental villi; *Si.* marginal sinus; *vi.* aborted extra-placental villi; *b.* decidual tissue. B. Portion of decidual tissue at *b* highly magnified; *v.* blood-vessels; *d.* decidual cells with one nucleus; *d'.* multinucleated decidual cells (*Minot*).

one-sixth that of the child. It consists of two portions, the fetal and maternal.

This organ consists of a fleshy mass lying between two

membranes. Upon the fetal surface, we find the AMNION and CHORION. The AMNION consists of a single layer of cuboidal epithelial cells that rest upon the mesodermal tissue. These epithelial cells possess prominent, deeply-staining nuclei, but the protoplasm does not react well to the stain. The mesodermal tissue is somewhat fibrillar, and few cells are present. It is avascular.

The CHORION is composed of mesodermal tissue in which the fibrils are more or less distinct. This mesoderm is covered by trophodermal (ectodermal) cells that later become the syncytium. From the side opposite to the amnion are seen projections. These may vary from small simple villi to those resembling a tree possessing an enormous number of twigs. Along this surface of the chorion, may be seen masses of a fibrillar substance that are called *canalized fibrin*. The bulk of the placenta consists of *villi*. These form a reddish spongy mass, divided into masses called *cotyledons*. The main stems contain two or more vessels surrounded by mesodermal tissue. Peripherally, each villus is covered by a thin layer of nucleated protoplasm, the *syncytium*. The small twigs consist of a core of mucous connective tissue supporting several small capillaries. The syncytium surrounds each twig. In places are seen collections of nuclei representing the *cell-knots*. The cavities between the villi are the *intervillous spaces* containing the maternal blood and, at times, canalized fibrin.

From this, it is readily seen that the *fetal and maternal blood currents do not intermingle*. They are separated from each other, the endothelium of the fetal capillaries on the one hand, and the syncytium of the villi on the other.

The maternal side of the placenta is covered by the DECIDUA SEROTINA, or the STRATUM COMPACTUM of the mucosa. It is less than a millimeter thick, and possesses a number of short oblique channels. These are the remains

of the uterine glands; they now represent *blood sinuses*, which contain maternal blood.

The serotina extends into the fetal portion as the *placental septæ*, and divides it into the cotyledons. At the edge of the placenta, it becomes attached to the chorion, and continues as the DECIDUA VERA. At this junction there is a considerable space that extends all around the edge of the placenta. This is the *marginal sinus*, and is prominent because few or no villi have developed here.

The MEMBRANES consist of the AMNION and the uterine lining, or the STRATUM COMPACTUM. The *latter* is thin, and contains neither glands nor epithelium. When the fetus increases in size and causes a dilatation of the uterus, the amniotic sac is forced against the uterine lining, and causes an atrophy of the glands and cells of the stratum compactum. As a result, a mere fibrinous membrane, that has a loose connection with the amnion, is produced, due entirely to pressure.

Fossati, by means of the Golgi method, found a peculiar network of fibres surrounding the blood-vessels of the placenta and umbilical cord; this network also seemed to come into relation with the epithelium. *He considered this network nerve tissue.*

The **Umbilical Cord** is the connecting link between the fetus and the placenta, and represents the early belly-stalk. It is surrounded by one or more layers of cuboidal epithelial cells, continuous on the one hand with epithelium of the amnion, and on the other with the ectodermal cells of the body, supported by a little subepithelial fibrous tissue. Within this covering is the peculiar tissue called WHARTON'S JELLY. This is embryonic connective tissue in which the cells are chiefly spindle-shaped; some round and stellate cells, however, are seen. The intercellular substance is semi-solid, and takes a peculiar homogeneous stain.

During the early months of pregnancy, the intercellular substance contains a great deal of water, and the cellular elements are few. At the end of pregnancy the intercellular substance is more or less fibrillar, though the semi-solid portion predominates. At this time the cells are mostly of the stellate type, but not numerous. At the body end, occasionally, traces of allantoic cavity and yolk sac are found.

The VESSELS contained are the *single* UMBILICAL VEIN and *two* UMBILICAL ARTERIES. These are thick-walled and well-

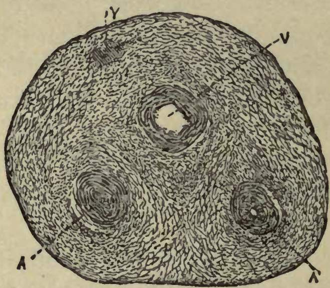


FIG. 78.—CROSS-SECTION OF HUMAN UMBILICAL CORD (*Minot*).
A, A'. Umbilical arteries; V. umbilical vein; Y. remains of allantois.

developed, and the muscle fibres run both circularly and longitudinally. The wall of the arteries is thicker than that of the vein. The insertion of the cord into the placenta is usually *eccentric*, and at this point the vessels branch rapidly and spread out in all directions.

The *circulation* of the placenta is a *closed one*. The blood is carried from the iliac arteries to the umbilicus through the *hypogastric arteries*, which continue in the cord as the *umbilical arteries*. These branch to follow the villi and ultimately terminate in tufts of capillaries in the terminal villous twigs. The blood at this point receives the oxygen and nutritive matter from the maternal blood that circulates

in the intervillous spaces in which the villi lie. There is *no direct communication between the fetal and maternal blood,* for they are separated from each other by the endothelium of the capillaries and the syncytium covering the villi. As the oxygen and nutritious substances pass into the fetal blood, the effete matter and gases pass out into the maternal blood. The principle is the same as in the lung, where the blood is oxygenated. Red cells never pass from one system to another, but leukocytes that have the power of ameboid motion may. The blood is collected by the radicals of the *umbilical vein* and carried into the body to the under surface of the liver, where a portion enters the portal vein through the continuation of the umbilical vein, is distributed to the liver and collected by the hepatic veins and emptied into the postcava; the remainder is carried to the postcava (inferior vena cava) by the *ductus venosus.* The blood passes to the right auricle, then through the *foramen ovale* to the left auricle, from which it passes, through the auriculo-ventricular orifice, into the left ventricle. The blood then passes into the aorta chiefly to the upper extremities and head, is collected by the radicals of the precava (superior vena cava), and emptied into the right auricle. From this chamber it passes through the auriculo-ventricular orifice into the right ventricle, from which it passes into the pulmonary artery toward the lungs. As these organs do not functionate at this time, most of the blood is sent to the aorta through the *ductus arteriosus.* The blood then passes toward the lower extremities, and, as it reaches the internal iliac arteries, most of it is sent to the placenta through the arterial trunks, which inside of the body are called the *hypogastric arteries,* and in the cord the *umbilical arteries.*

CHAPTER XVI.

THE SKIN AND ITS APPENDAGES.

The **Skin** covers the external surface of the body and is its most extensive organ. It consists of two portions, the **Epidermis,** or **Cuticle,** and the **Cutis Vera,** or **Corium.**

The **Epidermis** is the epithelial portion of which the appendages are modifications. It consists of *stratified squamous* cells, which, over the general body surface, are divisible into *two layers*, STRATUM MALPIGHII and STRATUM CORNEUM.

The STRATUM MALPIGHII, or RETE MUCOSUM, is composed of a number of layers of cells. The basal part consists of columnar elements, and is called the GENETIC LAYER. The cells stain deeply, and under certain conditions show pigment granules. The layer is uneven in its course, as it conforms to the waves of the corium. The upper cells of the stratum Malpighii are large polyhedral elements that do not touch one another, but are separated by intercellular spaces. Each cell is provided with a number of delicate *spines*, or *prickles*, that meet those of other cells, and thus prevent the cell-bodies from coming into contact with one another. These are the PRICKLE CELLS. As the upper part of this stratum is approached, the cells become flattened and have an even course.

The STRATUM CORNEUM ordinarily forms a thin layer. Its cells are very thin and scale-like and usually possess no nuclei. They are derived from the cells beneath, but differ from them in consisting of keratin that gives them their hard and horny characteristic. These cells are constantly cast off, and the cells below increase to replace them. Be-

tween these two layers an irregular STRATUM GRANULOSUM is often seen.

In certain parts of the body, sole and palm, the STRATUM GRANULOSUM and another, the STRATUM LUCIDUM, are well developed.

The STRATUM GRANULOSUM lies external to the stratum Malpighii, and is composed of two or three layers of flattened, spindle-shaped cells that contain a deeply-staining nucleus and coarsely granular protoplasm. The *granules* are *keratohyalin* that later form the horny matter of the stratum corneum. These granules are quite large and prominent, and respond well to hematoxylin. They seem to be modified protoplasm, but some hold that they represent products of the degenerating nucleus.

The STRATUM LUCIDUM lies external to the stratum granulosum, and separates this from the stratum corneum. It forms a narrow, glistening band of cells, two or three layers broad, in which the *keratohyalin* granules have fused to form a homogeneous substance, called *eleidin*. This substance reacts well to eosin. The nuclei are not prominent nor are the cell-bodies distinct.

The **Derma, True Skin,** or **Cutis Vera,** is composed of connective tissue arranged in two or more less distinctly separated layers. These are the STRATUM PAPILLARE, or *outer*, and the STRATUM RETICULARE, or *inner*.

The STRATUM PAPILLARE consists of delicate bundles of small white fibrils forming a close network with elastic fibres.

The upper portion of this stratum is thrown into small waves called the *papillæ*, to which the stratum Malpighii conforms. Over the general skin surface, these papillæ do not extend through the stratum Malpighii, but in the *palmar* and *plantar* regions they are visible externally, and cause the peculiar markings seen in these areas. These papillæ

are important, as they contain *either capillary plexuses* or *special sensor nerve beginnings.* The lower portion of the papillare consists of a looser network, in which the vessels

FIG. 79.—CROSS-SECTION OF SKIN OF SOLE OF FOOT.

a. Stratum corneum; *b.* stratum lucidum; *c.* stratum granulosum; *d.* stratum Malpighii; *e.* derma; *f.* panniculus adiposis; *g.* duct of sweat gland; *h.* prickle cells; *i.* genetic layer; *k.* cross-section of a smooth muscle fibre; *l.* duct of sweat gland; *m.* Pacinian body; *n.* secretory portion of sweat gland; *o.* muscle of tubule; *p.* blood-vessel; *q.* adipose tissue.

form plexuses parallel with the surface. It gradually passes into the STRATUM RETICULARE.

The STRATUM RETICULARE is not distinctly separable from the preceding. It is composed of larger bundles of coarser

fibrils of white fibrous tissue, and contains some yellow elastic tissue, as will be seen below. Here are found the larger blood-vessels and the appendages and special sensor nerve beginnings. In the corium of the scrotum, penis and nipple, smooth muscle fibres are found. When these bundles contract, "goose-flesh" is produced.

The elastica is often separated into layers, of which there are four, the *subepithelial*, *papillary*, *reticular* and *subcutaneous* elastic layers.

Beneath the stratum reticulare is usually a layer of adipose tissue that separates the skin from the fascia. This is the PANNICULUS ADIPOSUS, and it varies in thickness in the different regions.

The color of the skin is due to the presence of *pigment granules* in the lower layers of the stratum Malpighii. Such granules have been found even in the corium. In the white races, this pigmentation is limited to the nipple and genital region. Whether the pigment is due to the vital activity of the cells, or whether it is brought here and deposited, is not definitely settled. The former seems to be the origin of that of the retinal cells and probably of that of the skin.

The skin is the protective organ, and varies in thickness in the different regions. It is thinner on the less exposed surfaces, as the inner surfaces of the thighs and arms, and thicker on the exposed regions, as back, sole and palm.

Upon the palmar and plantar surfaces the epithelium is thrown into ridges. These are arranged in definite patterns characteristic of each individual. Recorded impressions of these surfaces have been used as means of identification for various purposes. Wilder considers the plantar patterns more characteristic than the palmar patterns.

The *blood-vessels* of the skin vary in size and number, according to the location; in the gluteal, plantar and palmar regions, they are greater, while in the most movable parts

they are most branched. The larger trunks lie in the reticulare, parallel to the surface, and form a capillary plexus in the papillare. From this plexus, capillary tufts enter the various papillæ. The latter vessels continue as venous capillaries, that form a plexus just beneath the papillæ. This empties into another in the lower portion of the derma that communicates with a subdermal plexus; the latter lies between the derma and the panniculus adiposus, and its vessels possess valves.

The *long nerve* trunks are found in the reticulare, and from these branches form a *subpapillary plexus*. Myelinated fibres extend toward the surface, and form the special beginnings.

The *sensor organs* are very numerous in the skin. These comprise the *free beginnings*, or those in which the naked axis cylinder pierce the epithelial layer, branch and send these divisions between epithelial cells. The higher forms of beginnings comprise *tactile corpuscles of Meissner*, most numerous in the palmar and plantar skin of the fingers and toes; *bulbs* of the conjunctiva and genitalia; *Pacinian bodies* especially in the palms and soles; and the *organs of Ruffini*, resembling the *neuro-muscular beginnings*. For a detailed description, see **Nerve Tissue** (p. 90). In addition, there is the usual nerve supply to the blood-vessels.

The *lymphatics* of the skin consist of *superficial*, or *papillary plexus*, which receives the lymph from the spaces in the papillæ, and a *deeper*, or *subcutaneous plexus* that consists of larger trunks, that anastomose with the above, and communicate with the special plexuses of the appendages.

THE APPENDAGES.

The **Appendages** of the skin are the **Hairs, Nails, Sebaceous, Sweat** and **Mammary Glands.** These are all derived from the epidermis.

THE HAIRS.

The **Hairs** are protective organs limited to certain portions of the body. Each consists of a ROOT, that portion within the skin, and a SHAFT, that part seen above the surface.

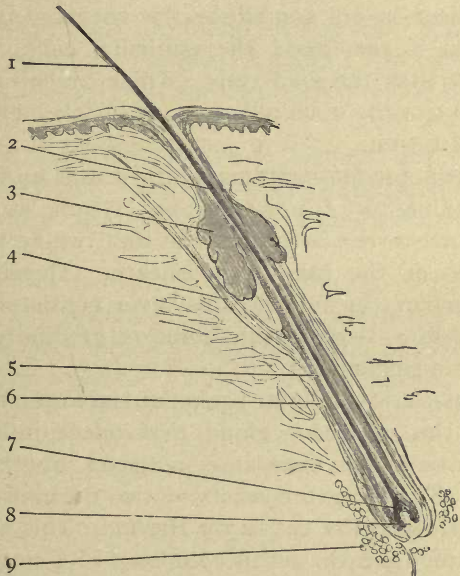


FIG. 80.—FROM A SECTION OF SCALP (*Stöhr's Histology*).
1. Hair-shaft; 2. hair-root; 3. sebaceous gland; 4. arrector pili muscle; 5. root sheaths; 6. follicular sheath; 7. hair-bulb; 8. papilla; 9. fat cells.

The ROOT is somewhat flask-shaped, the lower end being enlarged to form the HAIR-BULB. This, on its under surface, is indented and invaginated by a little mass of connective tissue, the HAIR PAPILLA, that contains a small tuft of capillaries, upon which the nourishment of the hair solely depends. The root is surrounded by a condensation

of the derma, in which the connective tissue bundles are arranged into two layers.

In the *outer*, the fibres have a longitudinal course, while in the *inner*, they run circularly. Within this circular layer is a prominent homogeneous band, the *glassy membrane*. This represents a greatly hypertrophied *basement membrane*. These layers constitute the FOLLICULAR SHEATH. Internal to it are found the epithelial cells, which are continuous with the epidermis. These are arranged into layers that are the ROOT SHEATHS, of which there are two, OUTER and INNER.

The OUTER ROOT SHEATH is the direct continuation of the stratum Malpighii. These cells are the same as elsewhere, and continue to the bottom of the root, where they blend with those of the inner root sheath. Throughout the greater part of the follicle, this layer consists of several rows of cells. Toward the bulb, it gradually becomes reduced to a single layer.

The INNER ROOT SHEATH begins at the lower edge of the orifice of the sebaceous gland that opens into the hair follicle. Above the duct it is replaced by the stratum corneum. This sheath consists of two portions, the *outer* of which is called the LAYER OF HENLE. This lies next to the outer root sheath, and is composed of a single layer of flattened cells. Within this layer is the sheath, or LAYER OF HUXLEY, which consists of two or three layers of large irregular cells. In the bulb all of these layers, including the outer root sheath, are inseparable, and gradually pass over into the hair itself.

The **Hair** occupies the central portion of the follicle, and is composed of three parts, CUTICLE, CORTEX and MEDULLA.

The CUTICLE is composed of a single layer of irregular, nonnucleated scales. These are very thin and overlap. Within the follicle they lie closely applied to the layer of

Huxley. The CORTEX consists of a great many layers of long, spindle-shaped elements. The nuclei are rod-shaped. The MEDULLA, when present, is composed of several rows of cuboidal cells that do not extend the length of the hair. They contain granules of keratohyalin, and frequently have a dark appearance; this is due to the presence of small air-bubbles.

The heaviest hairs are found on the scalp and pubis, in the axilla, and upon the face of males. Delicate hairs occur all over the body surface, and these are like the LANUGO HAIRS of the fetus.

The *color* of the hair is due to pigment granules in the cortex. These cells may even contain pigment in solution. Diffuse pigment is abundant in dark and red hairs, but absent in white.

Opening into the hair follicles are the SEBACEOUS GLANDS. This is usually upon the side toward which the hair leans, and here is also seen the muscle of the hair follicle, the ARRECTOR PILI muscle. This is smooth muscle, and is attached above to the derma, just beneath the stratum Malpighii, and below to the hair bulb. When it contracts it causes the hair to "*stand on end.*"

THE NAILS.

The **Nails** are peculiar appendages that serve for the protection of the ends of the fingers and toes, and consist of the ROOT and the NAIL-BODY.

The ROOT is the proximal end at which the organ grows. Here the epithelial cells are transformed into the hard substance that gives the nail its character. Along the sides, the nail is protected by an overhanging ledge of skin, which constitutes, at the root, the NAIL-FOLD, and at the sides, the NAIL-WALL. The angle formed by the nail and wall is the

NAIL-GROOVE. The stratum corneum continues into the angle over the edge of the nail as the EPONYCHIUM.

The NAIL-BODY consists of the NAIL PROPER and the NAIL-BED upon which the nail rests.

The NAIL *represents a greatly hypertrophied stratum lucidum.* The cells are flattened elements, in which the nuclei are indistinct, and the protoplasm clear. At the proximal end is the root, and at this place alone the nail grows. It is marked by a white area, the LUNULA. Here the epithelial layer is so thick that the underlying capillaries are invisible. The cells also are said to contain keratohyalin granules. At the distal end, the nail projects as the FREE EDGE.

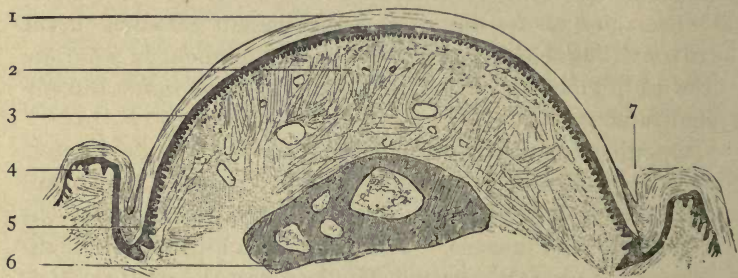


FIG. 81.—CROSS-SECTION OF NAIL.
1. Nail; 2. corium; 3. epithelium; 4. nail-wall; 5. nail groove; 6. bone of phalanx; 7. eponychium.

The NAIL BED consists of the stratum Malpighii and the corium. The stratum Malpighii resembles that of the skin surface, and rests upon the papillated corium. That portion beneath the lunula is termed the MATRIX. The corium is composed of bundles of white fibrous and yellow elastic tissues that have a general longitudinal direction. Between the bundles are vertical fibres that pass from the periosteum toward the nail. The PAPILLÆ of the bed are

not like those of the skin, but consist of long RIDGES that extend from the root to the end of the nail. They are small beneath the root, but increase in height as the free edge is approached, and end abruptly at that point.

THE GLANDS.

The **Glands** comprise the **Sweat, Sebaceous** and **Mammary Glands.**

The **Sweat-glands** are of the *coiled tubular* variety. Each consists of a *secretory portion* that lies in the stratum reticulare, and an *excretory duct* that passes up through the derma and cuticle to open upon the surface.

The SECRETORY PORTION consists of a *single layer of cuboidal* cells lining the tubule. These are separated from the *basement membrane* by a *layer of smooth muscle fibres.* The protoplasm is granular and may contain pigment granules and fat globules. The nucleus is usually quite distinct. The secretory tubule is coiled upon itself, and the various convolutions are separated from one another by interstitial tissue that corresponds to the tunica propria.

The DUCT that leads from the secretory part to the surface has usually one-half the diameter of the secretory tubule, and is lined by *two layers* of cells that rest upon a *basement membrane* and *tunica propria.* In the epidermis its course is spiral, and *no separate wall is present,* the epithelial cells of the epidermis acting in this capacity. The diameter of this portion is greater than that of the corium. Its opening upon the surface is large and trumpet-shaped, and is called the SWEAT-PORE.

These glands are generally distributed, *except on the margins* of the *lips*, *glans penis* and *inner surface of the prepuce.* They are most numerous in the palm and largest in the axilla. The average diameter is 1 mm., but

in the latter region they may attain a size of 3 or 4 mm. In this region the secretory tubule *may be branched*.

The *normal secretion is an oil* that keeps the skin soft and pliable. When the innervation becomes disturbed, the secretion becomes *thin and watery*, and is then termed *sweat*. The GLANDS of MOLL, of the eyelid, and the CERUMINOUS GLANDS, of the external ear, are coiled tubular glands that secrete oil alone.

The **Sebaceous Glands** are *racemose* structures. They are usually found in connection with the hair follicles; the largest hairs possess small glands, while the smallest hairs are appendages of the attached sebaceous glands. Each is surrounded by a capsule of white fibrous tissue that forms the supportive structure.

The ALVEOLI are lined by cells that are a continuation of the cells of the stratum Malpighii, and which rest upon a *basement membrane* and *tunica propria*. These cells are very large, and completely fill the alveolus. Those in the center, where the lumen should be, are further advanced in changes than the basal cells. The entire protoplasm becomes converted into oil, which constitutes the secretion, and is called SEBUM. The death of the cell is necessary to the formation of this secretion. The transformed cell is immediately replaced by another. The excretory duct is lined by several layers of cells that do not take part in the secretory activity, and are derived from the outer root sheath of the hair follicle.

Sebaceous glands are found in regions devoid of hairs, as in the *margins of the lips*, *glans penis*, *prepuce*, *glans clitoris* and *labia minora*.

THE MAMMARY GLAND.

The **Mammary Gland** is an *alveolo-tubular* organ. According to some writers, it is a *modified sweat gland*, while

others hold it to be a modified *sebaceous structure*. It is a *compound organ*, if such a term may be used, as it is composed of from fifteen to twenty individual compound glands. Each of these possesses its own excretory duct, that has its own opening in the nipple. The entire organ is covered by skin.

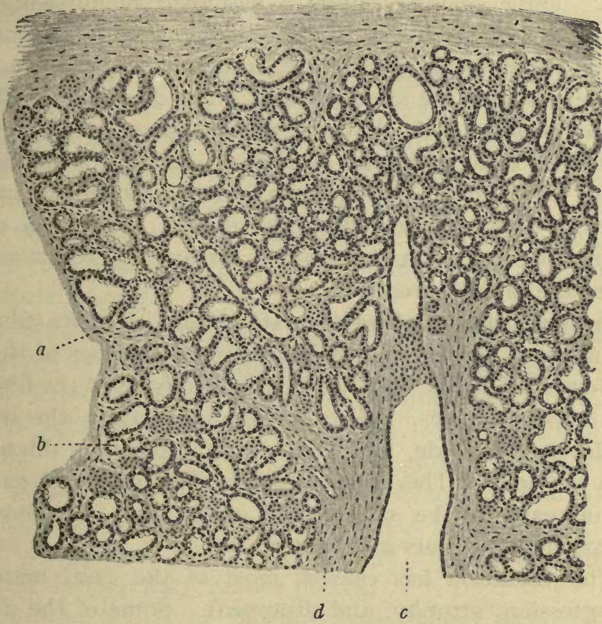


Fig. 82.—Section of Lactating Human Mammary Gland (*Stöhr's Histology*).
a. Alveolo-tubule; *b*. tubule; *c*. duct; *d*. connective tissue.

Each gland consists of *lobes* and *lobules* separated and supported by white fibrous and adipose tissues. All of the individual glands are further bound together in the same manner. The ducts converge and end in the nipple, which forms a small projecting mass.

Each *lobule* consists of a number of *acini*, which are tubular or alveolar in structure. The number of these depends upon the state of activity. In the *gland of pregnancy*, the *acini* are very numerous, and are lined by *simple columnar*, or *cuboidal* cells, in which are accumulated the fat globules that form the important constituent of the milk. These cells rest upon a basement membrane, but in places are separated therefrom by peculiar elements called basket cells, which are compared to the smooth muscle tissue of the sweat glands. The *ducts* are lined by *simple columnar* cells that rest upon a *basement membrane*, outside of which circular bundles of white fibrous tissue are to be found. These ducts unite to form the main secretory duct of the individual glands; each main duct dilates to form a small AMPULLA, OR SINUS LACTIFEROUS, before the nipple is reached.

The *nonlactating gland* consists chiefly of white fibrous and adipose tissues, in which are seen a number of ducts, but few acini. The bulk of the organ consists of the fibrous and adipose tissues. When pregnancy occurs, the ducts divide and redivide, and the terminal portions dilate to form the acini. This increase in the glandular part causes the increase in the size of the organ, and the tingling sensation that occurs at that time.

After lactation has ceased, most of the acini undergo retrogression, atrophy, and disappear. Some of the ducts undergo the same change. As a result, the gland becomes somewhat smaller and flabby. In old age, or after the child-bearing period has passed, the glandular and ductular portions retrograde and disappear in the same manner, until in old age, they may be entirely absent. The glands are then represented by fibrous and adipose tissues.

Milk consists of minute globules of fat, 0.1 to 0.5 mm. in diameter, surrounded by a thin layer of CASEIN. This

prevents them from coalescing. They are formed in the protoplasm of the cells of the acini, but the cell, after discharging them, does not die, as formerly supposed. At first, COLOSTRUM is present in the glands; this consists of fat and COLOSTRUM CORPUSCLES, which are either degenerated gland cells, or leukocytes.

The NIPPLE, or MAMMILLA, consists of an outer covering of pigmented skin, and within it the individual ducts are found. These are separated from one another by fibrous tissue and involuntary, nonstriated muscle. The muscle tissue is arranged circularly and vertically, extending to the apex of the mammilla. By its contraction, an erection is produced. Such tissue is called *false erectile tissue*. At the base of the nipple is a pigmented area called the AREOLA, which contains a ring of sebaceous glands called the GLANDS OF MONTGOMERY.

In addition to the general blood-vessels, the various appendages have special supplies. From the *subpapillary arterial plexus*, branches pass to the hair follicles, to form one plexus beneath the hyalin membrane, and another in the papilla. The venous radicals formed, empty into *subpapillary plexus of veins*. Around the sebaceous and sweat glands, the subpapillary arterial plexus forms a close network of capillaries which form venous branches that empty into the subpapillary venous plexus.

The *blood-vessels* of the mammary gland converge toward it, and pass into the organ in the partitions between the lobules. From these vessels, branches extend into the lobules, and form close plexuses around the acini.

The appendages are supplied with *nerves* from both sympathetic and cerebrospinal systems. The hair follicles receive myelinated fibres that branch freely, and end in *spoon-shaped masses* upon the glassy membrane. The sweat glands are supplied with sympathetic fibres, that

form a close network beneath the basement membrane, which they pierce, to end upon the gland cells. The mammary gland has both varieties of nerves. The sympathetic are the more numerous; these pass to the blood-vessels on the one hand, and to the acini on the other. In the latter, they form a plexus beneath the basement membrane, and from this plexus, branches end upon the gland cells. The nerve beginnings in the nipple are numerous.

The glands and hair follicles are surrounded by separate *lymphatic plexuses* that empty into the subcutaneous vessels. In the mammary gland, plexuses are found between the individual lobes, around the ampullæ and in the nipple. These empty into the axillary lymphatics.

CHAPTER XVII.

THE NERVE SYSTEM.

The **Nerve System** consists of the **Cerebrum, Cerebellum, Pons, Oblongata** and **Spinal Cord.** It is surrounded by three membranes, the **Dura, Arachnoid** and **Pia.**

The **Dura** is a tough membrane composed of interlacing bundles of white fibrous and yellow elastic tissues that contain lymph spaces between them. Within the skull, it forms the *inner periosteum* of the cranium, which relation ceases at the foramen magnum, the entrance into the vertebral canal. In the latter, it is not connected with the bone, but hangs like a bag and contains the spinal cord. This membrane is lined by *endothelial* cells, and forms the outer boundary of the SUBDURAL LYMPH SPACE. It is quite vascular, and a few nerves, that pass to the blood spaces are found.

The **Arachnoid** is a thin, delicate, web-like membrane composed of loosely interwoven bundles of white fibrous tissue. It lies closely applied to the dura, and is separated from the pia by the SUBARACHNOIDEAN LYMPH SPACE. This is also lined by *endothelial* cells. It forms the PACCHIONIAN BODIES and VILLI, but contains neither blood-vessels nor nerves.

The **Pia** is the *vascular membrane.* Its outer portion contains the bulk of the vessels, while the inner enters into close relation with the nerve tissue. Its blood-vessels lie in the fibro-elastic network, surrounded by PERIVASCULAR LYMPHATICS. Its arachnoidean surface is covered by

endothelial cells. Only a few nerve fibres are present. The pia is the only one of these membranes that follows the fissures and depressions of the nerve system.

The **Nerve System** consists of **Gray** and **White Substances.**

The **Gray Substance** consists of NERVE CELLS, their PROCESSES and NEUROGLIA, MYELINATED and AMYELINATED nerve fibres.

The NERVE CELLS are of various forms, *unipolar*, *bipolar* and *multipolar*. The first possess but *one process*, the second, *two*, and the third, *three* or *more*. The CELL-BODY may be of any shape, and consists of granular protoplasm that has a fibrillar structure. The NUCLEUS is usually large, but does not take a deep stain. The NUCLEOLUS is very large and stains deeply.

The PROCESSES are DENDRITIC and AXIS CYLINDER. The DENDRITES are *minor* processes that are subdivided into a great many smaller processes, the *teledendrites;* in certain instances, sensor cells, the dendrites may be myelinated (see **Nerve Tissue**, p. 84). The AXIS CYLINDER process, or NEURIT, is the *main* process. In cells of the FIRST TYPE, or DEITER CELLS, the neurit *leaves* the gray substance to become the center of a nerve fibre. In those of the SECOND TYPE, or GOLGI CELLS, the axis-cylinder *never leaves* the gray substance.

The NEUROGLIA consists of NEUROGLIA, or GLIA CELLS, and a fibrillar intercellular substance. The cells are either *spider* or *mossy*. For a detailed description of these, see the chapter on **Nerve Tissues** (p. 86).

The **White Substance** consists of MYELINATED NERVE FIBRES held together by NEUROGLIA and some white fibrous connective tissue.

In the **Cerebrum** and **Cerebellum**, the **Gray Substance** is *external*, and constitutes the CORTEX. The **White Substance** is *internal*, and is called the MEDULLA. In the

Spinal Cord, the **Gray Substance** is surrounded by the **White Substance.** In the **Oblongata** and **Pons,** there is no distinct arrangement.

CEREBRUM.

Beside the **Cerebrum,** there are other masses of nerve tissue to be considered here. These are the **Olfactory Lobes,** the **Pituitary** and **Pineal Bodies.**

The GRAY SUBSTANCE, or **Cortex** of the **Cerebrum,** is divided into layers that are not sharply limited from one another. In some regions, *five* can be made out, in others *three*, while *four* form the average number. The **Cortex** is made irregular by the formation of fissues and convolutions. The latter consist of a central mass of white substance, **Medulla,** covered by the gray substance, or **Cortex.**

The CORTICAL LAYERS are, from without inward, the 1, MOLECULAR, 2, SMALL PYRAMIDAL, 3, LARGE PYRAMIDAL and 4, MIXED OF POLYMORPHOUS LAYERS.

1. The MOLECULAR layer consists mainly of *neuroglia* and *cell-processes*. The *latter* are derived from the next two layers, and are chiefly *dendrites*. The *neuroglia* forms a network within which the dendrites and myelinated nerve fibres lie. The *latter* run parallel to the surface, and are therefore called *tangential fibres*.

Among the *cellular elements* are some of the *second type*, or *Golgi cells*. The *axis cylinders* of these cells *remain* in the gray substance. They are polygonal, stellate and spindle-shaped cells, in which the dendrites run parallel to the surface, and are called the CELLS OF CAJAL.

2. The LAYER OF SMALL PYRAMIDAL cells is composed of several layers of cells, the dendrites of which extend into the molecular layer, while some of the axis cylinders partially pass to the molecular layer (second type) and *others*

pass into the medulla (first type, or Deiter cell). In the *latter* case, the axis cylinders give off branches called

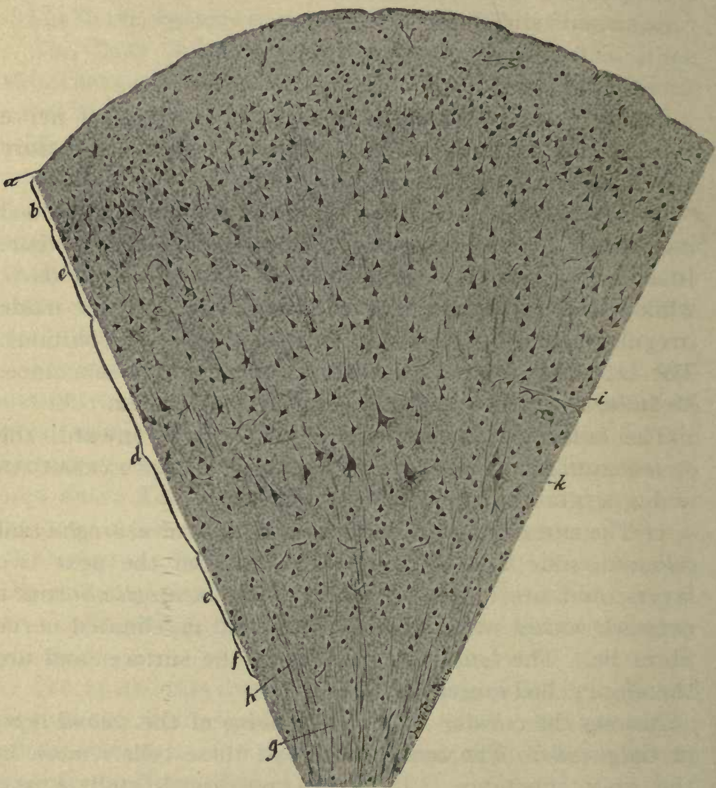


FIG. 83.—VERTICAL SECTION OF HUMAN CEREBRAL CORTEX.
a. Pia; *b*. molecular layer; *c*. small pyramidal cells; *d*. large pyramidal cells; *e*. layer of polymorphous cells; *f*. layer of fusiform cells; *g*. medulla; *h*. radial bundles of myelinated fibres in cortex; *i*. pial process; *k*. large pyramidal cell.

collaterals. The CELLS themselves are small, measuring 10 to 12 microns in diameter, and triangular in outline. The

DENDRITES arise from the *angles*, while the AXIS CYLINDER, or NEURIT, has its origin at the *middle of the base*.

3. The LAYER OF LARGE PYRAMIDAL cells constitutes the widest and most important layer. The CELLS are usually 20 to 50 microns in diameter, though some may exceed this. The dendrites pass to the molecular layer, while the neurit becomes myelinated nerve fibre. These cells are, therefore, cells of the *first type*. Their outline is triangular, and the nucleus is large and prominent.

4. The LAYER OF POLYMORPHOUS cells contains cells of various shapes; these are large and small pyramidal, spindle-shaped, oval and polygonal. The *latter* predominate. The dendrites pass to the upper layers of the cortex, while the axis cylinders, in some instances remain in the cortex, and in others pass into the medulla.

In the last three layers, bundles of myelinated nerve fibres having a radial course are seen. They begin in the small pyramidal layer, increase in number as they approach the medulla, and contain, beside those fibres derived from the immediate cortical cells, others whose origin is not definite.

In addition there are other myelinated nerve fibres that form layers practically parallel with the surface. The STRIATION OF BAILLARGER is composed of such fibres that lie in the large pyramidal cell layer. The STRIATION OF BECHTEREFF consists of myelinated fibres between molecular and small pyramidal cell layers.

The **Medulla** consists of MYELINATED NERVE FIBRES from various sources; those that pass to the periphery of the body from the pyramidal and polymorphous cells (PROJECTION FIBRES); others from the pyramidal cells that pass from one hemisphere to the other (COMMISSURAL FIBRES); those that connect different areas of the same side (pyramidal cells), and whose axis cylinders are "T"-

branched, and pass into the cortex sooner or later (ASSOCIATION FIBRES); lastly, fibres that come from distant parts of the same or the other hemisphere, or other parts of the nerve system (CENTRIPETAL FIBRES).

OLFACTORY LOBE.

The **Olfactory Lobe,** that portion of the nerve system devoted to the sense of smell, is comparatively small in man. There are *five* layers present, which are best marked in the central part of the organ. These are the LAYER OF PERIPHERAL FIBRES, the GLOMERULAR LAYER, the MOLECULAR LAYER, the LAYER OF MITRAL CELLS and the GRANULE LAYER.

The LAYER OF PERIPHERAL FIBRES consists of a plexus formed by the fibres of the OLFACTORY NERVES.

The GLOMERULAR LAYER lies beneath the above, and is made up of peculiar round, or oval, bodies 100 to 300 microns in diameter. They are said to be masses of *interlacing telodendria* of the olfactory and mitral cells.

The MOLECULAR LAYER is made up of large and small spindle-shaped ganglion cells whose dendrites end in the glomeruli, and whose axis cylinders pass to the FIFTH, or GRANULE LAYER.

The LAYER OF MITRAL CELLS consist mainly of large PYRAMIDAL cells varying in size from 30 to 50 microns. Their dendrites pass to the glomeruli and the axis cylinders to the granule layer.

The GRANULE LAYER consists of *nerve cells* and *fibres*. The cells are stellate, ganglion elements, and peculiar granule cells; the *latter* appear to have no axis cylinders. Some of the nerve fibres are derived from the mitral cells, some from the molecular layer, and others from the outside. The deeper bundles enclose granule and stellate cells.

THE HYPOPHYSIS.

The **Hypophysis** or **Pituitary Body,** is a small organ consisting of a NEURAL, or CAUDAL LOBE, the **Posthypophysis** and an EPITHELIAL, or FRONTAL LOBE, the **Prehypophysis.** Both are surrounded by a common capsule of fibrous tissue.

The PREHYPOPHYSIS, however, is divided into a number of *tubular alveoli* lined by *polygonal epithelial* cells. These cells are of two varieties, acidophilic and basophilic; the latter are the more numerous. Some contain large nuclei surrounded by a clear and slightly granular protoplasm, while others contain a similar nucleus buried in a coarsely granular protoplasm. These are irregularly arranged so that a small lumen remains; this may contain *colloid substance.* The nerves of this lobe consist of very few fibres with numerous branchlets and ramifications that follow the arteries to be distributed mainly to acini. Here they terminate in ball-like enlargements.

According to Berkley, the POSTHYPOPHYSIS consists of an outer layer of gray substance similar to that of the infundibulum, composed of slightly irregular endymal cells three to four layers deep; this tissue, however, is not found on the surface where the two lobes are in contact. The central part of this lobe consists of a few acini, that may contain colloid substance; these acini constitute about one-third of the cellular elements; the remaining two-thirds of the cellular elements are nerve cells of various forms as follows: 1. *Flask-shaped cells* with short axones and knob-tipped dendrites. These cells are widely distributed and the branches end freely between the other structures. 2. *Cells whose processes end in the endymal layer;* these are large ganglion cells the axones of which traverse the entire organ and end in the infundibular area. Large oval cells higher up also

belong to this group. 3. *Small elements* with short dendrites of a prickly appearance; these cells are unlike any other cells in the body. To this group belongs another small cell with an apical tuft of wavy processes.

The two lobes, although surrounded by an apparently common capsule, are absolutely distinct and are separated by a fibrous lamella. The posthypophysis alone is connected with the infundibulum.

The *arteries* reach the organ by means of the infundibulum. As they reach the fibrous septum between the two lobes branches pass to the prehypophysis and form plexuses between the acini. The capillary plexuses of the posthypophysis are likewise numerous. The *veins* have a corresponding return course.

The *lymphatics* are found in the lamella between the two lobes and consist of a network of spaces lined by simple ciliated cells; these probably represent endymal cells derived from the cavity of the infundibulum.

THE EPIPHYSIS.

The **Epiphysis,** or **Pineal Body,** is a small, apparently unimportant organ in man. In some lower animals, it is a *visual organ.* This rudimentary structure consists of a number of tubules lined by *polygonal cells* supported by fibrous tissue and neuroglia in the lower part. These tubules contain the BRAIN SAND, or ACERVULUS CEREBRI, peculiar concretions of phosphate and carbonate of magnesium, ammonium and calcium, which are not limited to this body, however, but may be found in other portions of the nerve system.

CEREBELLUM.

The **Cerebellum,** or **Little Brain,** has a characteristic gross appearance, when sectioned. Its **Cortex** and **Medulla**

are so colored and arranged as to give the appearance of a TREE, called the ARBOR VITAE, or TREE OF LIFE.

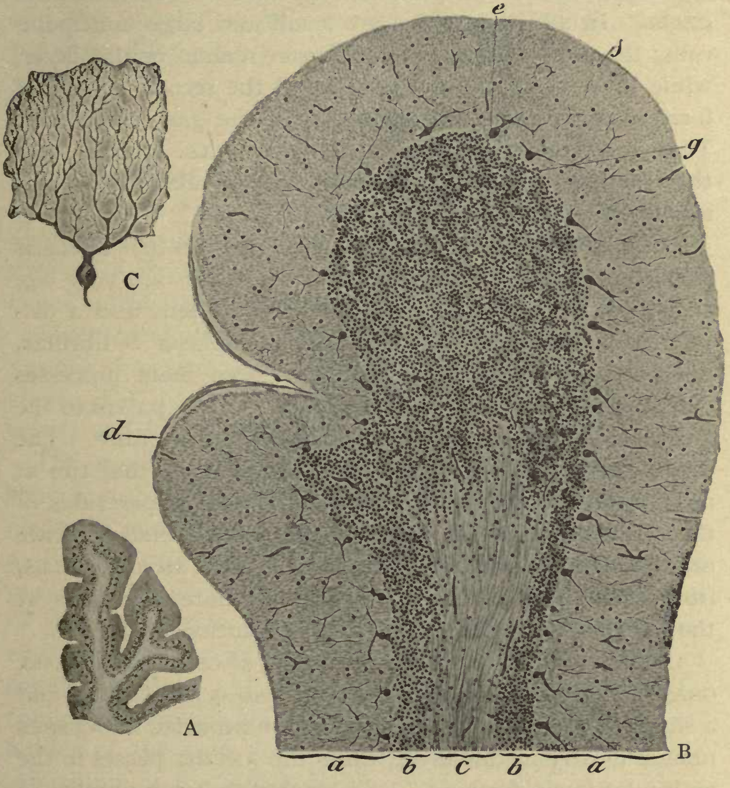


FIG. 84.—VERTICAL SECTION OF THE HUMAN CEREBELLUM.
A. Cerebellum, low power; B. cerebellum highly magnified; *a*. molecular and ganglionic l yers; *b*. granule layer; *c*. medulla; *d*. pia; *e*. cell of Purkinje; *f*. cell of molecular layer; *g*. cells of the granule layer; C. cell of Purkinje.

The **Cortex** consists of three sharply-marked layers, the 1, MOLECULAR, the 2, GANGLIONIC and 3, GRANULE LAYERS, from without inward.

1. The MOLECULAR LAYER consists of a network of neuroglia, in which the dendritic branches of the cells of the lower layers are found. They are mostly those of the GANGLIONIC CELLS. In addition, there are small and large multipolar cells; the axis cylinders of the *former* remain in this layer, while those of the *latter* pass toward the second layer and form a network of branches around the ganglionic cells. They are therefore called the BASKET CELLS. Fibres from the MEDULLA pass into this layer and break into a great number of delicate terminal twigs.

2. The GANGLIONIC LAYER, or LAYER OF PURKINJE CELLS, is very characteristic. The bodies of these cells are very big, measuring 30 to 70 microns. A large nucleus and a distinct nucleolus are present. The protoplasm is fibrillar, but contains no pigment granules. Two main processes extend from the body; the LOWER, or NEURIT, passes to the medulla and becomes a myelinated nerve fibre. The UPPER, or DENDRITIC, quickly breaks into two, that run at right angles to the main stem. From the upper sides of these two branches, an immense number of small, delicate branches are formed. These cells are called ANTLER CELLS, from their appearance. The cells are more numerous at the *top* than at the *bottom* of the convolutions.

3. The GRANULE LAYER is composed of GREAT and SMALL GRANULE CELLS. The SMALL CELLS possess large nuclei and a small amount of protoplasm. The DENDRITIC PROCESSES remain mostly in this layer, while the NEURIT passes to the molecular layer, forming "T" branches that run parallel to the surface. The LARGER CELLS resemble the cells of the ganglionic layer, but the AXIS-CYLINDER forms a network of branches, being a cell of the *second type*. Besides the *neuroglia* present, there are some fibres of the myelinated variety. This layer is thicker at the summit of the convolution, and diminishes as the base is reached.

The **Medulla** consists of myelinated nerve fibres, supported by neuroglia and connective tissue; of these fibres, some form the *inferior peduncles;* others the *middle* (*pontile*), and the remainder the *superior peduncles*, which connect the cerebellum with the corpora quadrigemina.

THE PONS.

The **Pons** can conveniently be divided into two portions, the VENTRAL PART or PONS PROPER, that can readily be distinguished by the naked eye, and the DORSAL or TEGMENTAL PART, which is continuous with the oblongata, and hence called PREOBLONGATA.

The **ventral portion** consists mainly of FIBRES running in various directions and separated by masses of gray substance, the PONTILE NUCLEI. The FIBRES course *transversely* and *longitudinally*.

The *transverse fibres*, at the caudal portion of the pons lie superficial to the pyramids; at a higher level the fibres increase in number and are often described in three groups: a. *Ventral superficial fibres*, those that pass ventral to the pyramids; b. *dorsal*, or *deep*, fibres, those that pass dorsal to the pyramid; c. *penetrating*, or *middle*, those that pass right through the pyramids and break into a number of smaller bundles. At the cephalic level of the pons all the transverse fibres again form a single mass. At the lateral border of the pons these transverse fibres pass into the cerebellum as the *medipeduncles*. As to origin these fibres are of two kinds: 1. those that arise in the cerebellar cortex and end in the pontile nuclei and, 2. those that arise in the pontile nuclei and end in the cerebellar cortex.

The *longitudinal fibres* are those that constitute the pyramid; at the upper and lower portions of the pons these fibres form a single compact bundle, while in the middle

region they are separated into smaller bundles by the transverse penetrating fibres.

The *gray substance* of this portion of the pons consists of

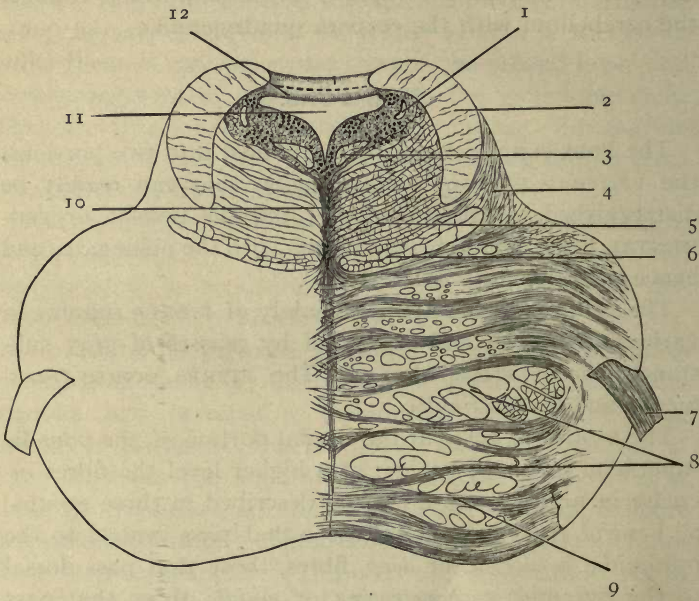


FIG. 85.—DIAGRAM OF TRANSVERSE SECTION OF CEPHALAD PORTION OF PONS (*Morris, after Schwalbe*).

1, Mesencephalic root of trigeminal nerve; 2, prepeduncle; 3, Median longitudinal bundle; 4, lateral lemniscus; 5, formatio reticularis; 6, medial lemniscus; 7, trigeminal nerve; 8, pyramidal fasciculi; 9, transverse fibers of pons; 10, raphé; 11, fourth ventricle; 12, metatela.

many collections of nerve cells in the spaces between the fibre bundles; these are the *pontile nuclei.*

At the boundary zone between pons and preoblongata lies a bundle of transverse fibres that arise from cells in the nuclei of termination of the cochlear division of the auditory nerve; these fibres cross to the opposite side of the organ

and form here in the mesial region, by their decussation, the *trapezium*. From the trapezium the fibres continue toward the side of the preoblongata and form here the *lateral lemniscus*, which will be described later.

The PREOBLONGATA, or TEGMENTAL PORTION of the pons, lies dorsal to the preceding structures and includes the

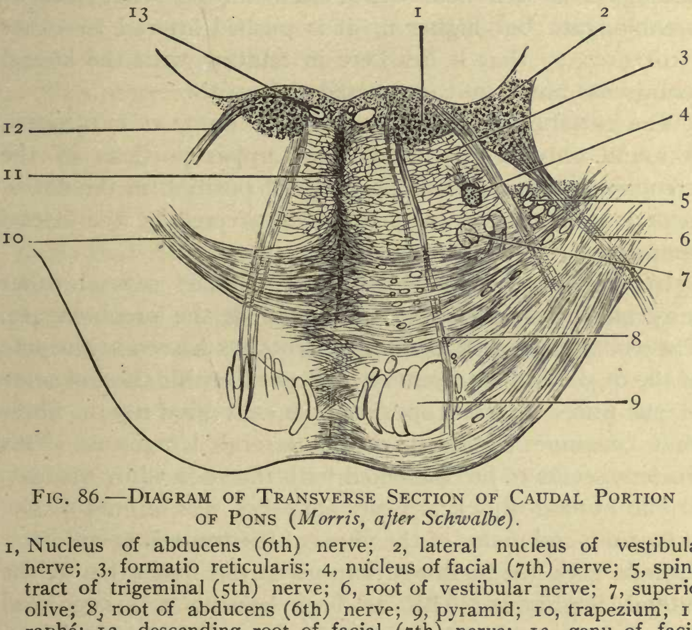


FIG. 86.—DIAGRAM OF TRANSVERSE SECTION OF CAUDAL PORTION OF PONS (*Morris, after Schwalbe*).

1, Nucleus of abducens (6th) nerve; 2, lateral nucleus of vestibular nerve; 3, formatio reticularis; 4, nucleus of facial (7th) nerve; 5, spinal tract of trigeminal (5th) nerve; 6, root of vestibular nerve; 7, superior olive; 8, root of abducens (6th) nerve; 9, pyramid; 10, trapezium; 11, raphé; 12, descending root of facial (7th) nerve; 13, genu of facial nerve.

cephalic portion of the *floor of the fourth ventricle*. The gray substance is found mainly as a layer just beneath the endyma of the ventricle; at various levels it forms nuclei *of origin* (*motor*) or *termination* (*sensor*) of the trigeminal, abducens, facial and auditory nerves. Between these nuclei and the trapezium is found the FORMATIO RETICU-

LARIS. Beneath the ventricle gray and near the midline is a bundle of fibres, the MEDIAN LONGITUDINAL BUNDLE. Laterally is formed a bundle of ascending fibres constituting the continuation of the fibres of the trapezium, called the LATERAL LEMNISCUS.

The MEDIAL LEMNISCUS continued cephalad from the oblongata is seen near the midline in the lower part of preoblongata, but higher up it is pushed laterad by other structures, so that it lies here in relation with the lateral lemniscus, but is not connected therewith.

The PREPEDUNCLE, or SUPERIOR CEREBELLAR PEDUNCLE, is found only in the middle and upper portions of the preoblongata, occupying a superficial position in the dorso-lateral area; higher up it becomes covered by the lateral lemniscus.

In addition to the cranial nerve-nuclei several other gray masses of importance are seen in the preoblongata. The NUCLEUS OF THE LATERAL LEMINSCUS is seen at the side of the organ and represents a nucleus of termination of some of the fibres of the trapezium; its cells give rise to fibres that continue cephalad in the lateral lemniscus. This nucleus seems to be connected with the succeeding nucleus.

The SUPERIOR OLIVARY NUCLEUS lies just laterad of the trapezium and many of the fibres of the trapezium end here; its cells give rise to fibres that aid in the formation of the lateral lemniscus. This nucleus lies at a lower level (caudad) than the preceding, but seems connected with it.

THE OBLONGATA.

The **Oblongata,** or **Postoblongata**, consists of halves like the spinal cord, but here the resemblance ceases, as the arrangement of gray and white substances is different. The H-shape of the gray substance is no longer retained; that

portion in relation with the canal still remains about the same, but the horns are modified and broken by the PYRAMIDAL DECUSSATION and the FORMATIO RETICULARIS. As the canal is followed upward and is seen to broaden into the fourth ventricle, or METEPICELE, the gray substance that surrounded the canal becomes merely the floor of the ventricle. The remaining gray is seen as isolated masses forming nuclei, as the GRACILE, CUNEATE, OLIVARY, ARCUATE and PYRAMIDAL NUCLEI.

The SUBSTANTIA GELATINOSA ROLANDI continues from the spinal cord as the same mass forming a cellular mass at the side of the oblongata, the TUBERCULUM ROLANDI.

The cause of the rearrangement of the ventral gray substance is the PYRAMIDAL DECUSSATION. As the motor fibres that compose the pyramid are about to enter the cord, 85 to 90 per cent. take an oblique course from the ventral to the lateral portion of the opposite side of spinal cord, continuing here as the *crossed pyramidal tract.* In crossing, the ventral horn of gray substance is cut into two portions, that around the canal the *basal* part and the isolated *ventral mass* that is pushed laterad. The *ventral ground bundle* of the oblongata becomes covered by the pyramid so that the bundle becomes more dorsally placed as the oblongata is ascended.

In the caudal portion of the oblongata other marked changes are noted *dorsally.* As the funiculus gracilis (Goll) and the funiculus cuneatus (Burdach) enter the oblongata from the spinal cord they form two broad masses that consequently force the dorsal gray horns laterad so that ultimately these gray masses lie opposite each other at the sides of the oblongata. Ultimately the *basal* (canal) and *lateral* portions of the gray substance become separated from each other by nerve fibers that run in various directions, constituting the FORMATIO RETICULARIS. Thus, as

ventrally, the gray substance of the dorsal horn becomes separated into a *basal* (canal) *portion* (connected with the ventral basal gray) and an isolated *lateral mass*, that is associated with the spinal root of the trigeminal nerve.

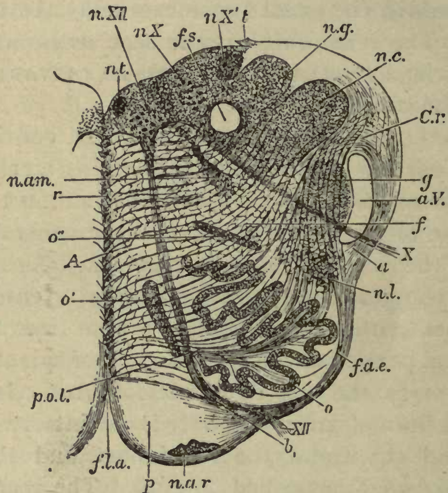


FIG. 87.—SECTION OF THE OBLONGATA AT ABOUT THE MIDDLE OF THE OLIVARY BODY (*Gordinier, after Schwalbe*).

f.l.a., Ventro-median fissure; *n.ar*, arcuate nucleus; *p*, pyramid; *X*II, hypoglossal nerve; *f.a.e.*, external arcuate fibers; *n.l.*, nucleus lateralis; *g*, substantia gelatinosa; *a.V.*, ascending root of fifth nerve; *X*, vagus nerve; *f.r.*, formatio reticularis; *C.r.*, restis being formed; *n.c.*, nucleus cuneatus; *f.s.*, funiculus solitarius; *n.X*, and *n.X'*, two portions of vagal nucleus; *n XII*, hypoglossal nucleus; *r*, raphé; *A*, beginnings of ventral column of the spinal cord; *o' o''*, accessory olivary nuclei; *p.o.l.*, peduncle of olive; *n.am*, nucleus ambiguus.

In connection with this *dorsal basal gray* arise two new gray masses, the NUCLEUS GRACILIS and NUCLEUS CUNEATUS.

The NUCLEUS GRACILIS is a mass of gray substance that lies close to the dorso-median groove and increases in size as the funiculus gracilis ends. It represents the nucleus of

termination of the fibres of the funiculus gracilis, or column of Goll. The cephalic end of this nucleus is connected with the gray substance of the canal area.

The NUCLEUS CUNEATUS lies laterad of the preceding;

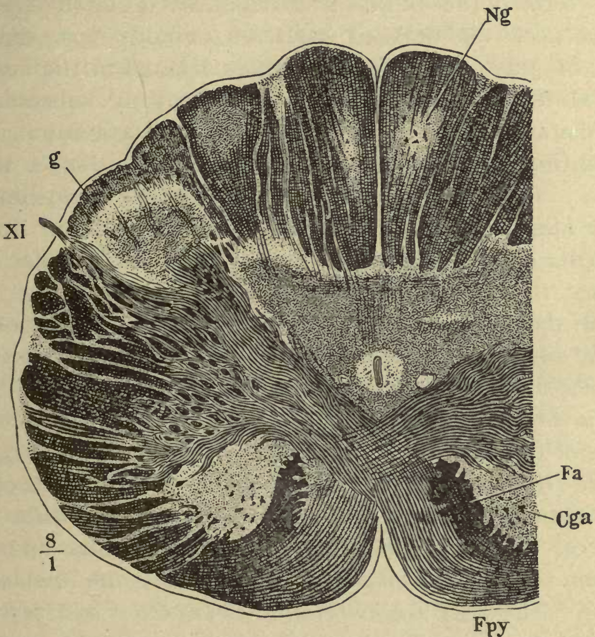


FIG. 88.—TRANSVERSE SECTION OF THE OBLONGATA THROUGH THE MOTOR DECUSSATION. (*Goedinier, after Henle*).

Fpy, Ventral pyramid; Cga, ventral horn; Fa, beginning of ventral column of spinal cord; Ng, nucleus gracilis; g, substantia gelatinosa; XI, spinal accessory nerve.

at its origin it is connected with, and represents an offshoot of, the central gray substance. It is the nucleus of termination of the fibres of the funiculus cuneatus.

Cephalad to the *motor*, or *pyramidal decussation*, is a second crossing of fibres involving those of sensor function,

the SENSOR DECUSSATION, or DECUSSATION OF THE FILLET. After crossing the midline the fibres form a bundle called the FILLET, or MEDIAL LEMNISCUS. These *ascending* fibres arise in the nuclei gracilis cuneatus, and in crossing have also been termed the DEEP, or INTERNAL ARCUATE FIBRES.

The INFERIOR OLIVARY NUCLEUS, or BODY, is an isolated mass of gray and white substances located in the ventro-lateral region of the oblongata. The gray substance is peripherally placed in the form of a thick wavy lamina that is wanting at the mesial side of the body; this space is the *hilum*. The central part of the body consists of myelinated nerve fibres that leave or enter through the hilum. In the immediate neighborhood of the olive are two smaller gray masses, the *dorsal* and *mesial accessory olivary nuclei*.

The ARCUATE NUCLEUS is found along the ventral portion of the oblongata cephalad to the pyramidal decussation. It is a flattened mass of gray substance; here end some of the fibres of the superficial arcuate band, while other fibres of this band arise from the cells of this nucleus.

The FORMATIO RETICULARIS lies in the lateral area of the oblongata and consists of a network of gray and white substances. The gray is more abundant laterally and this portion thence receives the name *formatio reticularis grisea*. The cells are *associative* in function and serve to connect the various levels of the oblongata with one another. The *formatio* near the midline is almost devoid of nerve cells and is called the *formatio reticularis alba*. The fibers of the formatio have both a *transverse* course (*deep arcuate fibres*) and a *longitudinal* direction.

The RESTIS, RESTIFORM BODY, or inferior CEREBELLAR PEDUNCLE, is found in the dorsal portion of the oblongata. It is composed of the direct cerebellar fibres of the spinal cord; fibres from the nuclei gracilis and cuneatus of the same side, the *dorsal superficial arcuate fibres;* fibres from the oppo-

site nuclei gracilis and cuneatus, the *ventral superficial arcuate fibres;* fibres from the opposite olivary body, the *olivo-cerebellar fibres.* The last seem to form the bulk of the restis.

The LATERAL TRACT consists of fibres of the lateral ground bundle of the spinal cord and fibres of the lateral columns, not including the direct cerebellar and crossed pyramidal tracts. The ground bundle fibres enter into the formation of the formatio reticularis, while the remaining fibres continue toward the cerebrum.

The VENTRAL PYRAMID, or PYRAMIS, consists of *motor* fibres from higher centers to the spinal cord.

THE SPINAL CORD.

This portion of the nerve system is the longest. It is characterized by possessing the gray substance internally and the white substance externally. Its form varies in the different regions; in the cervical and lumbar areas, it is enlarged, and these enlargements are termed the INTUMESCENTIA CERVICALIS and LUMBALIS, respectively. The outline in the *cervical* region is *oval*, in the *thoracic* region almost *circular*, and in the *lumbar* portion *oval.*

The cord ends in the neighborhood of the upper border of the second lumbar vertebra, and its termination is cone-shaped. This is called the CONUS MEDULLARIS. Owing to the fact that the cord is shorter than the vertebral canal, the lower lumbar, the sacral and coccygeal nerves pass down for varying distances before reaching their respective foramina. This produces a mass of fibres in the lower part of the canal called the CAUDA EQUINA. In the center of the latter is a fibrous band that extends toward the end of the canal. It is the FILUM TERMINALE.

The **Cord** consists of two hemispheres separated ventrally by the VENTRAL, or ANTERIOR MEDIAN FISSURE, in which is

seen a process of the pia. Dorsally, no fissure exists, but a SEPTUM is present. This is the DORSAL, OF POSTERIOR MEDIUM SEPTUM, OF RAPHE.

The gray substance of the cord is arranged in the form of a letter **H**, the two side bars constituting the HORNS, and

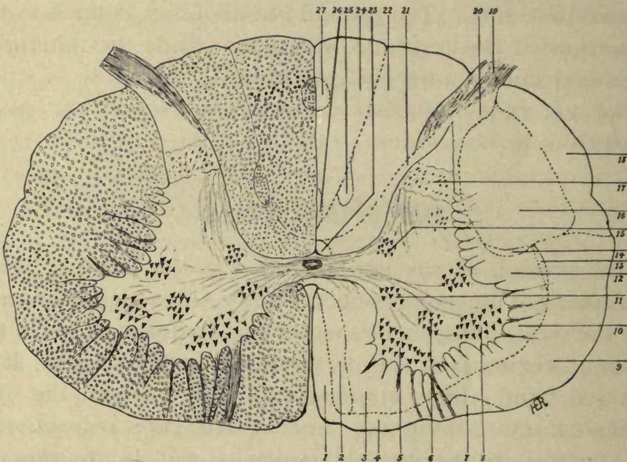


FIG. 89.—A COMPOSITE DIAGRAM OF ALL LEVELS OF THE SPINAL CORD.
1, Sulco-marginal tract; 2, direct pyramidal tract (Türck); 3, ventral ground bundle; 4, vestibulo-spinal tract (Loewenthal); 5, ventro-median group of cells; 6, central group of cells; 7, spino-olivary tract (Helweg); 8, ventro-lateral group of cells; 9, tract of Gowers; 10, lateral ground bundle; 11, dorso-median group of cells; 12, mixed lateral tract; 13, spino-thalamic tract; 14, rubro-spinal tract; 15, dorsal nucleus (Clarke); 16, crossed pyramidal tract; 17, cell group of dorsal horn; 18, direct cerebellar tract; 19, dorsal (sensor) root; 20, tract of Spitzka (marginal); 21, dorsal ground bundle; 22, dorso-external column (Burdach); 23, cornu-commissural tract; 24, dorso-internal column (Goll); 25, comma tract of Schutze; 26, septomarginal tract (Bruce); 27, oval bundle of Flechsig.

the cross-bar the GRAY, DORSAL, OF POSTERIOR COMMISSURE. The HORNS are further subdivided into VENTRAL, OF ANTERIOR, and DORSAL, OF POSTERIOR. In the thoracic region a LATERAL HORN is described.

The VENTRAL HORNS are large and blunt, and do not extend to the periphery. In them are found collections of large, multipolar ganglion cells having a MOTOR function. The axis cylinders of the cells pass out of the ventral portion of the cord as the VENTRAL ROOT OF THE SPINAL NERVE. These cells average 60 to 120 microns, and are quite numerous. Each is surrounded by a distinct lymph space. They are collected into various groups which vary according to the region of the cord. The following are the most important: 1. CERVICAL REGION: VENTRO-MEDIAN, DORSO-MEDIAN, VENTRO-LATERAL, INTERMEDIATE, DORSO-LATERAL. 2. THORACIC REGION: VENTRAL, INTERMEDIATE. 3. LUMBAR REGION: VENTRO-MEDIAN, CENTRAL, VENTRO-LATERAL, DORSO-LATERAL (see Fig. 89).

The DORSAL, OR POSTERIOR HORNS are sharp and pointed, and usually extend to the edge of the cord. The cells here are small in number and size, averaging from 15 to 20 microns, and are scattered along the external margin. They comprise *marginal cells* whose axis cylinders pass into the lateral columns after passing through the substantia gelatinosa; *spindle-shaped* cells, the neurits of which pass into the dorsal columns; *stellate* cells, the axis cylinders of which pass into the dorsal columns of Burdach.

The LATERAL HORNS are most marked in the thoracic and upper cervical and third and fourth sacral regions. Each is formed, chiefly, by the *intermediate cell group*. The axones of these cells probably do not pass into the ventral roots but terminate within the cord at various levels of the same and opposite sides. They are probably closely connected with the sympathetic system and vasomotor and sweat-gland nerves.

Along the median edge of the horn, near its junction with the gray commissure, lies a group of cells that extends from the cervical to the mid-lumbar region. This is the VESICU-

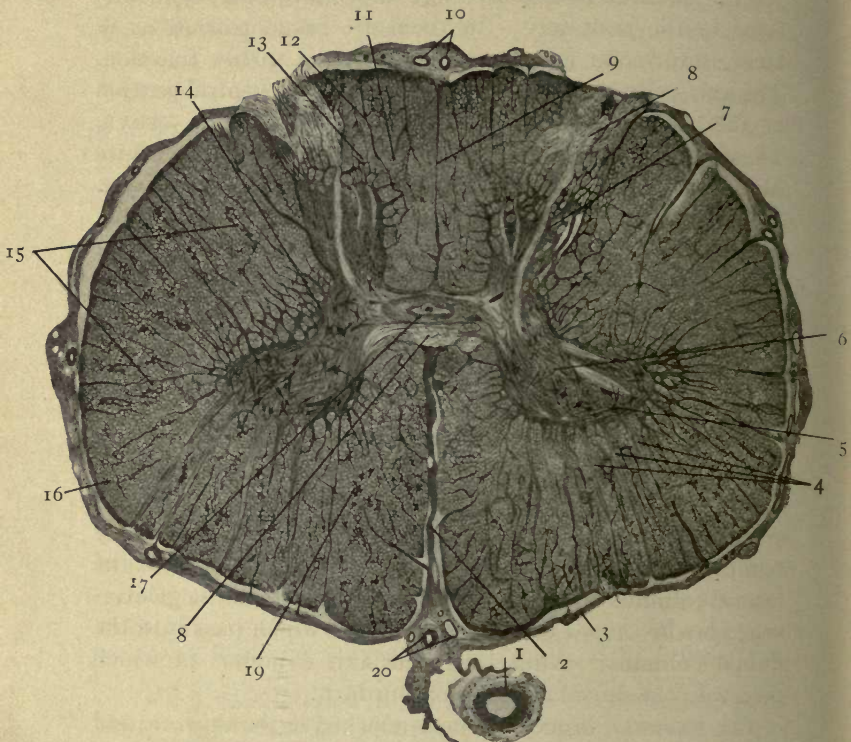


FIG. 90.—CROSS-SECTION OF HUMAN SPINAL CORD AT LOWER CERVICAL REGION. From Decapitated Criminal (Dr. H. H. Cushing).

1. Ventral spinal artery; 2. pial process in ventral fissure; 3. dura; 4. nerve fibres from ventral horn (motor root fibres); 5. stellate cells of ventral horn; 6. ventral horn; 7. dorsal horn; 8. nerve fibres of dorsal horn (sensor root fibres); 9. dorsal septum; 10. dorsal spinal artery and vein (arteria et vena fissuræ posterioris); 11. fibres of the column of Goll; 12. tissue separating the columns of Goll and Burdach; 13. column of Burdach; 14. traces of the lateral horn; 15. fibres of the lateral columns; 17. central canal in the gray commissure; 18. ventral, or white commissure; 19. fibres of the ventral columns; 20. arteria et vena fissuræ anterioris.

LAR COLUMN OF CLARK. A similar collection, though less distinct, lies just ventral of Clark's column and extends through a greater part of the cord. This is the NUCLEUS OF STILLING and is represented in the oblongata by the *accessory cuneate nucleus*.

The neurits of these cells of the DORSAL HORNS pass into the DORSAL COLUMNS; those of the VESICULAR COLUMN OF CLARK pass into the DIRECT CEREBELLAR TRACT, on the same side and into the VENTRAL (ANTERIOR) COMMISSURE. In the dorsal horn is the SUBSTANTIA GELATINOSA ROLANDI, which consists of cells of the *second type* (*Golgi*).

The GRAY COMMISSURE consists of myelinated and amyelinated commissural fibres separated into VENTRAL (smaller) and DORSAL (larger) bands by the CENTRAL CANAL of the cord. The ventral portion is called the VENTRAL, or ANTERIOR GRAY COMMISSURE, while the other receives the name of DORSAL, or POSTERIOR GRAY COMMISSURE. The whole is the GRAY, or DORSAL COMMISSURE, in contradistinction to the VENTRAL, or WHITE COMMISSURE.

The CANAL of the cord is the remains of the embryonal cavity within this portion of the nerve system. In childhood, it is lined by simple ciliated elements, the ENDYMAL CELLS. Above, it communicates with the fourth ventricle, and its form varies in the different portions of the cord. It becomes more or less obliterated with increasing age, partially by increased growth of the lining ENDYMAL cells and partially by the ingrowth of neuroglial processes.

Besides the nerve cells, processes and fibres, the gray matter contains that peculiar supportive tissue found only in the nerve system, called NEUROGLIA. This substance is ectodermal in origin.

NEUROGLIA consists of two varieties of cells, or *astrocytes*, SPIDER and MOSSY. The SPIDER cells are composed of thin, flat bodies from which extend long, slender processes. The

MOSSY cells have short, heavy processes. In addition to these, there are some cells that possess large bodies and few processes. Fibres that, apparently, have no connection with any cell are seen passing over or under cell bodies. These processes all interlace to form a network for the support of the nerve cells and their processes. This substance is the SUBSTANTIA SPONGIOSA. Around the central canal of the cord, the substantia spongiosa becomes more modified, and is called the SUBSTANTIA GELATINOSA CENTRALIS. The network is much closer in this region. Around the dorsal horns, it forms a homogeneous, striated mass, in which a few nerve cells are found. This is the SUBSTANTIA GELATINOSA ROLANDI, CAPUT GLIOSIUM, or GLIOSA CORNUALIS.

The WHITE SUBSTANCE consists of myelinated nerve fibers, connective tissue, and neuroglia. Spider cells are especially numerous here. The nerve fibres possess no neurilemma, and are grouped into columns. Ventrally, they are separated by the fissure, and dorsally, by the septum, into the hemispheres. Ventrally, they are connected by a band of white substance that lies between the bottom of the fissure and the gray commissure. This is the WHITE, or VENTRAL (ANTERIOR) commissure. The MOTOR fibres are usually large, measuring 15 to 20 microns in diameter. The SENSOR are smaller.

The following columns are not found in any one section of the cord but represent all that are definitely bounded. Fig. 89 represents merely a diagramatic section locating all the columns.

The VENTRO-MEDIUM columns that lie between the ventro-median fissure and the ventral roots of the spinal nerves; the LATERAL, that lie between the ventral and dorsal roots, and are subdivided into VENTRO-LATERAL, or those ventral to the transverse midline, and the DORSO-LATERAL, or those behind the same line. The DORSO-

MEDIAN columns lie between the septum and the dorsal roots of the spinal nerves, subdivided into DORSO-INTERNAL and DORSO-EXTERNAL.

These areas are further subdivided into individual columns. In the VENTRO-MEDIAN region, there are several groups: 1. the DIRECT PYRAMIDAL TRACT (TÜRCK). This is a narrow band of fibres that lies along the fissure, and represents the nondecussating fibres from the motor regions of the brain. The bundle lies next to fissure in thoracic region and disappears in the lumbar part of the cord. A *descending* tract.

2. The SULCO-MARGINAL TRACT is found only in the cervical part of the cord and consists of fibres from opposite quadrigemina and represents a *descending tract*. It lies next to the fissure.

3. The VENTRAL VESTIBULO-SPINAL TRACT (Loewenthal's) lies at ventral surface of the cord in cervical and thoracic portions and consists of *descending* fibres.

4. VENTRAL GROUND BUNDLE. This consists of fibres that arise in the cord and end in the cord, extending up and down for short distances in order to connect the various segments of the cord. These fibres are *associative* in function.

In the LATERAL region of the cord are the following tracts:

1. SUPERFICIAL VENTRO-LATERAL, or SPINO-CEREBELLAR (GOWERS) lies in the superficial ventral portion of the lateral area. The fibres probably arise from cells on both sides of cord in visceral and partly ventral regions and are *ascending*.

2. SPINO-OLIVARY, or HELWEG'S TRACT, lies just lateral to the ventral root and is found only in cervical and upper thoracic portions of the cord and represents *ascending* fibres.

3. DIRECT SPINO-CEREBELLAR TRACT lies in the superficial

dorso-lateral area and consists of *ascending* fibres from the cells of the column of Clark. This tract is not found in the lower lumbar region of the cord.

4. CROSSED PYRAMIDAL TRACT, is in the dorso-lateral region of the cord and is composed of fibres that *descend.* In the cervical region it is internal to the direct cerebellar tract but in the thoracic area of the cord it comes partially to the surface, and in the lumbar region, where the direct cerebellar tract is absent, the crossed pyramidal tract lies entirely superficial.

5. LATERAL GROUND BUNDLE lies against the gray substance and consists of *associative* fibres of both *descending* and *ascending* courses.

6. LATERAL MIXED TRACT occupies the remainder of the lateral columns and in it several tracts have been more or less completely outlined as follows (see Fig. 89):

a. RUBRO-SPINAL, *descending.*

b. CEREBELLO-SPINAL, *descending.*

c. Lateral VESTIBULO-SPINAL, *descending.*

d. OLIVO-SPINAL, *descending.*

These collectively are also termed the FASCICULUS INTERMEDIUS.

In the DORSAL region are seen the following tracts:

1. FASCICULUS GRACILIS (COLUMN OF GOLL) lies adjacent to the dorso-median septum and consists of *ascending* fibres that arise in the cells of the spinal ganglia (the axonic processes). These fibres end in the nucleus gracilis.

2. FASCICULUS CUNEATUS (COLUMN OF BURDACH) lies peripheral to the preceding, and likewise consists of fibres (axones derived from the cells of the spinal ganglia that *ascend*).

3. The DORSAL GROUND BUNDLE lies next to the gray substance of the dorsal horn and consists of short fibres that *ascend* and *descend;* they are *associative* in function.

4. The COMMA TRACT of SCHUTZE occupies a position in the tract of Burdach at the boundary line with the tract of Goll. Its fibres are *descending.*

5. The MARGINAL TRACT, OR TRACT OF SPITZKA, OR LISSAUER, is located along the dorsal root or among its fibres. It consists of some of the axones, of cells of the spinal ganglia, which traverse not more than three or four segments and end around the cells in the gliosa cornualis. It is *sensor* in function and is probably concerned with transmission of pain sense. All of the above tracts are found in all levels of the cord.

6. The DORSAL CORNUCOMMISSURAL TRACT is *associative* in function, consisting of both *ascending* and *descending* fibres.

7. The SEPTOMARGINAL TRACT (Bruce) consists also *associative* in function and lies along the postseptum. Its fibres *ascend* and *descend.* Both of these tracts are most distinct in the lumbar region of the cord.

The gray substance of the cord can be subdivided *functionally* into the following categories: 1. SOMATO-MOTOR; 2. VISCERO-MOTOR; 3. VISCERO-SENSOR; 4. SOMATO-SENSOR, as shown in Fig. 91. The course of the various components of the nerve-roots is likewise shown.

The SPINAL NERVES consist of VENTRAL, MOTOR, OR EFFERENT, and DORSAL, SENSOR, OR AFFERENT ROOTS. Before these unite to form the nerve, a mass of gray substance is seen *upon the dorsal root.* This is the SPINAL GANGLION. The fibres of the DORSAL ROOT are derived from the cells that lie in the ganglia, and where they enter the cord, a distinct depression is noted. The fibres peripheral to the ganglion represent *myelinated dendrites* and those that enter the dorsal root of the spinal cord represent the *myelinated axones.* Upon examining Fig. 91 it will be seen that the dorsal root is *not purely sensor,* but also con-

tains *viscero-motor fibres*. The VENTRAL ROOT is made up of fibres derived from the cells in the ventral horn, and where they emerge only a slight incurving of the surface is seen.

The *circulation* of the nerve system is carried on chiefly by the vessels in the pia. In the CEREBRUM, the vessels of

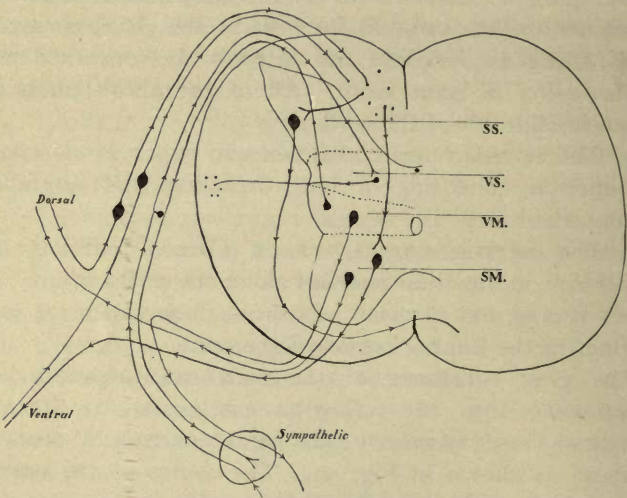


FIG. 91.—A DIAGRAM OF THE COMPONENT ELEMENTS OF THE SPINAL CORD AND ITS NERVE-ROOTS IN A TRUNK-SEGMENT ILLUSTRATING THE FOUR FUNCTIONAL DIVISIONS OF THE NERVE SYSTEM. (*After Johnston.*)

SS, Somatic sensor; VS, visceral sensor; VM, visceral motor; SM, somatic motor. The arrow heads indicate the directions of the impulses. *Note that visceral motor impulse passes out through the dorsal root.*

the cortex enter vertically, and form a close plexus of capillaries most plentiful where the cells are. Those intended for the medulla are larger, and, passing through the cortex, form capillary networks between the fibres and parallel to them.

In the CEREBELLUM, the capillaries are few in the outer

portion of the molecular layer, but in the granule layer and around the cells of Purkinje, close meshes are formed.

In the SPINAL CORD, there are two sets of vessels, those that enter at all points of the periphery and supply chiefly the white matter, and those derived from the artery lying in the ventro-median fissure; the latter set goes to the gray substance. The smaller peripheral vessels remain in the white substance, and run parallel to the fibres, while the larger penetrate the gray substance and supply the outer part. The artery in the fissure sends branches into the gray commissure; these divide right and left, and form dense plexuses in the gray substance.

The blood is collected by *venous* radicals that have the same general course.

The SUBARACHNOIDEAN LYMPH SPACE continues as the PERIVASCULAR LYMPHATICS that accompany the blood-vessels.

CHAPTER XVIII.

THE EYEBALL AND LACRIMAL SYSTEM.

The **Eyeball** is one of the most important organs of the special senses. It is composed of THREE COATS, and contains FOUR REFRACTIVE MEDIA. The COATS are the **External,** or **Corneo-sclera**; the **Middle,** or **Choroid, Ciliary Body** and **Iris**; and the **Internal,** or **Retina.**

The REFRACTIVE MEDIA are the CORNEA, the AQUEOUS and VITREOUS HUMORS and the LENS. Of these, the cornea and lens *alone* are of importance.

The **Corneo-sclera** is the protective and transparent coat of the eyeball.

The **Sclera** constitutes about five-sixths of this coat. It is composed of coarse bundles of white fibrous tissue that interlace to form a dense, tough coat. These bundles are arranged chiefly longitudinally and transversely. Between the bundles are spaces that contain large, stellate cells. These spaces communicate with the lymph spaces within the cornea. On its external surface, the sclera is in relation with the CAPSULE OF TENON, and, anteriorly, the CONJUNCTIVA. To it are attached the ocular muscles.

Between the sclera and choroid is a lymph space called the SUBSCLERAL SPACE. Here the tissue is loosely arranged and lined by endothelial cells. At the exit of the optic nerve, the sclera is pierced by the nerve fibres so as to form a sieve-like area, the LAMINA CRIBROSA. Pigmentation occurs here, as well as at the corneo-scleral junction. Its presence in the subscleral tissue gives rise to the LAMINA FUSCA.

The **Cornea** is a specialized portion of the sclera modified for the transmission of light. It consists of FIVE LAYERS: ANTERIOR EPITHELIUM, ANTERIOR LIMITING MEMBRANE, SUBSTANTIA PROPRIA, POSTERIOR LIMITING MEMBRANE, and POSTERIOR ENDOTHELIUM.

The ANTERIOR EPITHELIUM is a continuation of the epithelium of the conjunctiva. This is of the *stratified squamous* variety, and the *tunica propria* beneath is not papillated. The layers of cells are more numerous at the corneo-scleral junction than in the center. The basal cells are long and columnar, and possess processes that extend into the anterior elastic lamina, while the external cells are squamous. The middle layers are prickle-cells, and the spaces between are lymph channels.

The ANTERIOR ELASTIC LAMINA, or BOWMAN'S MEMBRANE, is a clear, prominent band serving as a basement membrane to the epithelial cells. Although called elastic, it does not consist of elastic tissue. It is thickest in the center, and becomes thinner as the junction is approached, where it disappears entirely.

The SUBSTANTIA PROPRIA forms the bulk of the cornea, and consists of a number of layers (about sixty) of white fibrous tissue arranged parallel to one another. It is due to this arrangement that this organ is transparent. In addition to these fibres, there are others that penetrate the organ at a right angle to the layers, and bind all together. These are the *perforating fibres*. Between the various layers are a large number of irregular spaces called the CORNEAL LACUNÆ. These contain large stellate cells that are the original connective-tissue cells of the organ. They are the CORNEAL CORPUSCLES. The spaces communicate with one another by means of little canals called CANALICULI, into which their processes extend. These spaces are readily shown by the gold chlorid method of staining.

The POSTERIOR LIMITING MEMBRANE, or MEMBRANE OF DESCEMET, is analogous to the anterior membrane; unlike this one, however, it is thicker peripherally than centrally, and seems more independent of the substantia propria than the anterior. It does not respond to the elastica stain, and, consequently, is not made up of elastic tissue, as its name would seem to indicate. It becomes the *pectinate ligament.*

The ENDOTHELIAL LAYER consists of a single layer of well-defined regular cells, which cover the posterior surface of this organ, and continues over the anterior surface of the iris. These cells are hexagonal, and possess a fibrillar protoplasm that seems to extend through several layers.

The cornea possesses *blood-vessels* during the developmental period; these, however, disappear before birth, so that none are then present. Lymph, which circulates through the many spaces and canaliculi, nourishes the cornea.

The sclera possesses but few vessels, and these are found chiefly at the corneo-scleral junction, where a circular network is formed.

The *nerves* are SENSOR; at the corneo-scleral junction a circular plexus is formed, from which fibres pass into the substantia propria, while others penetrate the anterior elastic lamina to pass into the epithelial layer. Some of these fibres extend almost to the surface.

The **Middle Coat,** or tunic, also called the **Uveal Tract,** is the vascular coat. It contains the main vessels of the eyeball, except the central artery of the retina, and consists of the **Choroid, Ciliary Body** and **Iris.**

The **Choroid** is the vascular portion, and is divided into three layers, the STROMA LAYER, the CHORIO-CAPILLARIS, and the GLASSY MEMBRANE, from without, inward.

The STROMA LAYER is sometimes referred to as the layer of large vessels, as they are found only in this portion. It

consists, externally, of delicate fibres that connect with those of the subscleral tissue and form a complete space, the SUPRACHOROIDAL, or SUBSCLERAL LYMPH SPACE. In this tissue are found pigmented connective-tissue cells, and it has received the name of LAMINA SUPRACHOROIDEA. The main portion of the stroma layer consists of bundles that are closely arranged. The network formed by these are the

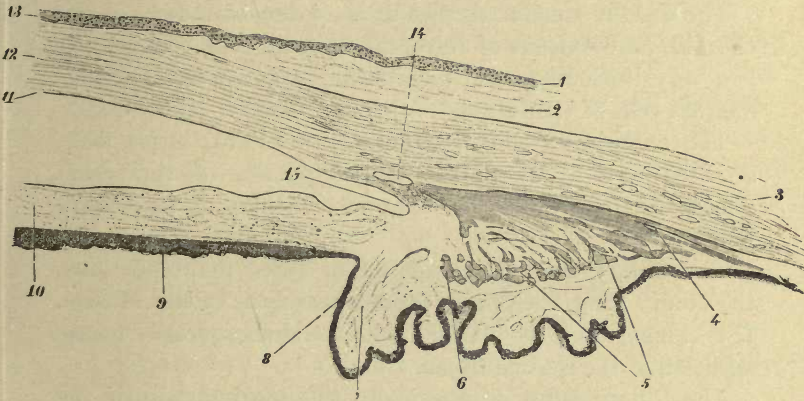


FIG. 92.—CORNEO-SCLERAL JUNCTION OF MAN.

1. Epithelium; 2. connective tissue of conjunctiva; 3. sclera; 4, 5, 6, 7 and 8. ciliary body; 4. meridional; 5. radial; 6. circular fibres of ciliary muscle; 7. ciliary process; 8. pars ciliaris retinæ; 9. pars iridica retinæ; 10. stroma of iris; 11. posterior elastic lamina of cornea; 12. substantia propria; 13. epithelium; 14. canal of Schlemm; 15. angle of iris, or infiltration angle (*Stöhr*'s *Histology*).

venous trunks, *externally*, and the *arterial* trunks, *internally;* the *latter* are accompanied by bundles of smooth muscle tissue. Pigmented cells exist between the bundles.

The inner portion of this layer is called the BOUNDARY ZONE; the bundles are arranged into several layers in herbivorous animals, so as to give a peculiar *metallic reflex*, and constitutes the TAPETUM FIBROSUM. This area is usually

free from pigment cells. In the carnivorous animals the fibres are replaced by distinct cells that contain crystals. The metallic reflex, however, is the same. This forms the TAPETUM CELLULOSUM.

The CHORIO-CAPILLARIS contains little stroma, and is composed chiefly of a dense capillary plexus. No pigment cells are seen. The capillaries are most numerous around the macula latea.

The GLASSY MEMBRANE lies at the inner boundary of the choroid, and consists of refractile, homogeneous tissue. It is a very thick basement membrane, and supports the pigmented cells of the retina.

The choroid extends to the ORA SERRATA, a peculiar, serrated line, at which the neural portion of the retina ceases. At this point, the choroid continues as the **Ciliary Body.**

The **Ciliary Body** is composed of three main portions, the **Ciliary Ring,** the **Ciliary Processes** and the **Ciliary Muscle.** It is thicker than the choroid, which is due especially to the addition of the muscle tissue.

The **Ciliary Ring** is practically the continuation of the stroma layer of the choroid and the boundary membrane, and consists of dense white fibrous tissue, which forms a circular band about 4 mm. in breadth. The vessels have a longitudinal course.

The **Ciliary Processes** are projections of the stroma, covered by pigmented epithelial cells, from 60 to 80 in number. They arise at the junction with the choroid, and extend toward the iris, increasing in height, ending abruptly at that point. At this place they are about 1 mm. in height. Each process consists of a core of stroma (connective tissue) supporting blood-vessels and covered by the pigmented epithelial cells of the retina, the PARS CILIARIS RETINÆ. These cells rest upon a continuation of the glassy mem-

brane. There are two layers, the *outer*, or *basal* of which consists of low columnar or cuboidal elements that are the continuation of the true pigmented cells of the retina. The *inner* layer is composed of cells that are columnar, possess little or no pigment, and are the representative of the optical portion of the retina.

The **Ciliary Muscle** is of the nonstriated variety, and lies external to the ciliary ring, just beneath the sclera. The fibres are arranged in MERIDIONAL, RADIAL and CIRCULAR sets. The MERIDIONAL are the *outermost*, and extend from the canal of Schlemm, in the corneo-scleral junction, to the ciliary ring. These are the *tensor muscles* of the choroid. The RADIAL fibres, which compose the *middle* layer, extend peripherally, and, spreading fan-like, are inserted into the ciliary ring and processes. The CIRCULAR fibres are the *inner* ones, and their direction is *equatorial*. They constitute MUELLER'S RING-MUSCLE.

The ciliary region is indicated, externally, by a band about one-fourth of an inch broad, starting at the corneo-scleral junction. It is called the danger zone of the eyeball, as injuries here usually result fatally to sight.

The **Iris** is the continuation of the stroma layer and glassy membrane of the choroid. It receives also the posterior lamina and the endothelium of the cornea, and consists of the ANTERIOR ENDOTHELIUM, STROMA LAYER, POSTERIOR LAMINA and PIGMENT LAYERS.

The ANTERIOR ENDOTHELIUM is a continuation of that of the cornea, and covers the anterior surface of the iris. The cells are neither so regular nor distinct as those of the cornea.

The STROMA LAYER is composed chiefly of a coarse network of white fibrous tissue, some of which is circularly arranged around the blood-vessels, which possess no muscular coat. Anteriorly, this stroma is very much reticulated

and forms a support for the endothelial cells. According to some authors, this portion constitutes an *anterior limiting membrane*. In the stroma layer, pigment cells are found in varying quantities; in gray eyes, very few are seen; as the color passes to blue, brown and black, the number increases, the last possessing the most. In albino eyes not only are the pigmented connective cells of the stroma layer absent, but the pigment that is usually present in the posterior epithelial cells continued from the retina is also absent. As a result of this, the retinal blood-vessels cause a peculiar red reflex, the *retinal reflex*. In the other eyes the pigment obscures it.

In the stroma, is found muscle tissue of the involuntary nonstriated variety. This is arranged CIRCULARLY and RADIALLY. The CIRCULAR fibres are near the anterior part of the iris, and contract the pupil when stimulated; these form the SPHINCTER PUPILLÆ muscle. The RADIAL fibres lie near the posterior part, and when they contract, the pupil is dilated; they constitute the DILATOR PUPILLÆ muscle.

The POSTERIOR LIMITING MEMBRANE, or MEMBRANE OF BRUCH, is a continuation of the glassy membrane. It supports the pigmented cells, the PARS IRIDICA RETINÆ.

The PIGMENTED LAYER, a continuation of the pars ciliaris retinæ, and called the PARS IRIDICA RETINÆ, is usually pigmented, and consists of two layers of cells. It continues to the anterior margin of the pupil.

The PUPIL is the aperture in the iris. Its size is regulated automatically by the amount of light entering.

The **Corneo-scleral junction** is the region in which cornea, sclera, ciliary body and iris come together. The sclera passes over into the cornea, but the line of transition is not abrupt, but gradual, and forms an oblique line that extends from before, backward and inward. Beneath the posterior

margin, usually within the sclera, is a *circular canal*, the CANAL OF SCHLEMM, which extends around the corneo-scleral junction. In this region, the membrane of Descemet is seen to divide into a large number of fibres that extend to the base of the iris. Between the fibres are found many intercommunicating spaces called the SPACES OF FONTANA. These spaces lie around the angle formed by the cornea and iris, called the INFILTRATION ANGLE, and communicate with the anterior chamber and the canal of Schlemm. The network is called the PECTINATE LIGAMENT, and is covered by endothelial cells.

THE RETINA.

The **Retina** forms the INTERNAL, or NEURAL COAT of the eyeball. It may be divided into two portions, the PARS OPTICA, that portion capable of vision, and the PARS CECA, or the blind part, possessing no nerve elements. The latter portion is further subdivided into PARS CILIARIS and PARS IRIDICA RETINÆ. The simplest division of the retina, however, is PARS OPTICA, PARS CILIARIS and PARS IRIDICA RETINÆ.

The PARS OPTICA lines almost the entire optic cup, and extends forward to the end of the choroid. Here the neural portion ceases, and the coat becomes abruptly thinner, and forms an irregular serrated line, the ORA SERRATA. From this point, the last two portions of the retina continue.

The optical portion consists of *eleven layers*, counting the pigmented layer. These layers are classed as NEURO-EPITHELIAL and CEREBRAL. The NEURO-EPITHELIAL portion consists of the first five layers within the pigment layer, and the CEREBRAL portion the remaining divisions. The pigmented part is derived from the outer layer of the optic cup, and the other parts from the inner layer.

Optic Vesicle.	Retinal Layer.	Classes.
1. Outer Layer.	PIGMENTED LAYER . . .	PIGMENT LAYER.
	LAYER OF RODS AND CONES.	
	EXTERNAL LIMITING MEMBRANE	NEURO-EPITHELIAL LAYER.
	OUTER GRANULAR LAYER.	
	HENLE'S FIBRE LAYER.	
2. Inner Layer	OUTER RETICULAR (MOLECULAR).	
	OUTER GANGLIONIC (INNER GRANULE).	
	INNER RETICULAR (MOLECULAR).	CEREBRAL.
	INNER GANGLIONIC.	
	NERVE FIBRES.	
	INTERNAL LIMITING MEMBRANE.	

1. The PIGMENT LAYER consists of polyhedral cells containing a black, granular, mobile pigment. The position occupied by this pigment depends upon the presence or absence of the light. The nonpigmented nuclei occupy the basal portion of the cells. These cells continue over the ciliary body and iris as the PARS CILIARIS and IRIDICA RETINÆ. In the iris, both layers are pigmented, but not in the ciliary region. This layer is derived from the outer layer of the optic cup.

The nerve structures are supported by NEUROGLIA, of which a great deal is present and unevenly distributed.

2. The LAYER OF RODS AND CONES is the most important portion of the retina.

The CONES consist of CELL-BODY and CONE-FIBRE. The CELL-BODY is about 30 microns in length, and is divided into two segments, *outer* and *inner*. The *outer* is conical, may be striated, rests upon the limiting membrane, and is apparently composed of discs. The *inner* segment is striated and flask-shaped. At its junction with the outer segment, it is granular, and the other part is fibrillar. The *cone-fibre*

ends in the outer reticular layer, and has a nucleus near its junction with the body.

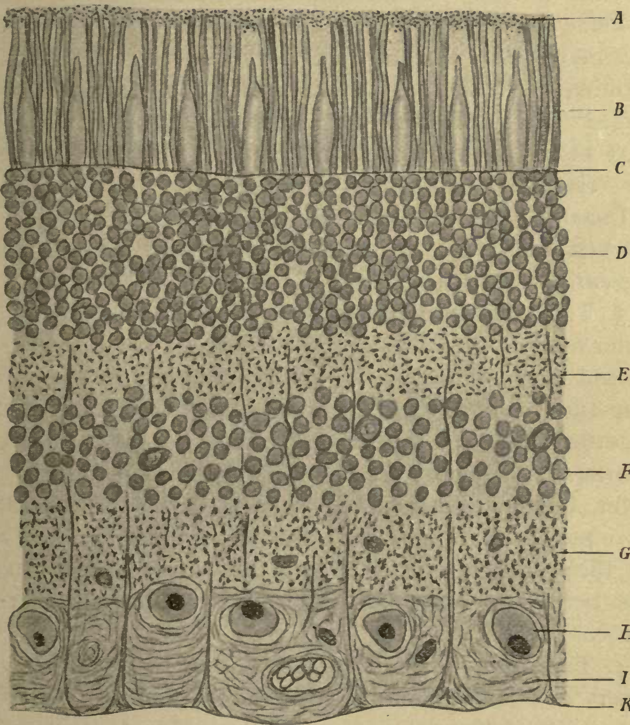


FIG. 93.—SECTION OF HUMAN RETINA (*after Piersol*).

A, Part of pigment layer; *B*, layer of rods and cones; *C*, external limiting membrane; *D*, (outer) nuclear layer; *E*, outer reticular layer; *F*, outer ganglionic layer; *G*, inner reticular layer; *H*, inner ganglionic layer; *I*, layer of nerve fibers; *K*, inner limiting membrane. Henle's fiber-layer is not represented.

The RODS are longer than the cones, averaging about 50 microns. They have somewhat the same structure as the preceding and are almost uniform in size. The different

segments react differently to stains. The *outer* segment possesses prominent cross and faint longitudinal striations. In this portion of the cell, the RHODOPSIN, OR VISUAL PURPLE, is located. The *inner* segment is spindle-shaped, granular, and fibrillar like the above. The *rod fibres* terminate in the outer reticular layer, where they are enlarged. The nuclei lie in the outer granular layer. They may be irregularly placed, and in lower animals may even be striated.

Usually three or four rods are seen to each cone. In the central portion of the yellow spot the *cones alone are present*.

3. The EXTERNAL LIMITING MEMBRANE consists of the outer ends of the fibres of Müller. These run radially, and extend through almost the entire thickness of the retina. The outer ends of these fibres are enlarged, and lie so close together that they form a membrane, the OUTER LIMITING MEMBRANE. These fibres do not penetrate the rod and cone layer, but give branches to all of the other layers. Each fibre possesses a nucleus that lies in the inner nuclear layer. At their internal ends, they are again enlarged, and form the INTERNAL LIMITING MEMBRANE. Glia cells are also present.

4. The GRANULE, OR NUCLEAR LAYER consists of several layers of oval nuclei, which are the granules. These are the nuclei of the rod and cone-fibres. The former are the more numerous.

5. HENLE'S FIBRE LAYER is best developed in the macular region, from which area it diminishes peripherally. It is made up of the inner segments of the rcd and cone-fibres.

6. The OUTER MOLECULAR, OR RETICULAR LAYER is composed of the inner ends of the rod and cone cells, which are branched, and fibrillar, and proceed from the inner nuclear layer.

7. The OUTER GANGLIONIC, or INNER GRANULAR LAYER is made up of several varieties of closely packed cells, the most numerous of which are OVAL, BIPOLAR ELEMENTS. These are placed vertically, and the small amount of protoplasm present continues as an inner process that passes to the inner molecular layer; here it breaks into many branches that form a network around the ganglion cells. The outer processes of these oval cells surround the ends of the rod-fibres in the form of a delicate rete, or mesh of fibrillæ.

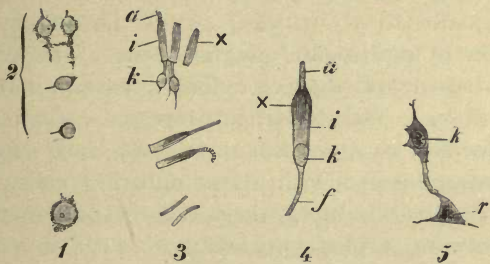


FIG. 94.—CELLS FROM RETINA OF AN APE (*Stöhr's Histology*).
1. Cell of ganglionic of layer. 2. Cells of inner granule layer. 3. Rod-cells: *a.* outer egment; *b.* inner segment; *k.* rod-granule; *x.* fibre apparatus. Below are rod-cells and fragments. 4. Cone-visual cells: *a.* outer segment; *i.* inner segment; *k.* cone-granule; *f.* cone-fibre; *x.* fibre apparatus; 5. Radial fibre, Müller's fibre: *k.* nucleus; *r.* pyramidal base.

Other cell-processes pass to the cone-fibres and to the inner molecular layer.

Another kind of cell is present, the AMAKRINE CELL, which forms a layer near the inner boundary of this nuclear layer. These cells possess no axis cylinders, but other processes extend into the inner molecular layer.

A third variety possesses a cell-body, the long diameter of which lies parallel to the surface of the retina. The processes pass into the outer molecular layer. Some connect with the rod-fibres; these are larger and lie internally,

while the others that pass to the cone-fibres are smaller and have an external position.

In addition to the above, there are some cells present in this layer that send their axis cylinders into the optic nerve.

The nuclei of Müller's fibres lie in this layer.

8. The INNER RETICULAR, or MOLECULAR LAYER consists of fibrils of cells of the preceding layer and from cells of the inner ganglionic layers. The fibres lie at different levels, which gives them a striated appearance.

9. The GANGLIONIC (INNER) LAYER is composed of a single layer of multipolar ganglion cells. The cell-bodies are flask-shaped, and the axis cylinders pass into the layers of nerve fibres. The dendritic processes extend into the inner molecular layer at different levels, and, supposedly, do not communicate with those of other cells. In the region of the macula lutea, these cells become increased in number, forming, often, eight layers.

10. The LAYER OF NERVE FIBRES is the expanded optic nerve. These fibres pierce all the layers, except the internal limiting membrane. They arise, mainly, from the cells of the inner ganglionic layer, converge at the *blind* spot, pass through the cribriform lamina of the sclera and become myelinated. As most of the fibres pass from the ganglion cells toward the brain, it would be better to say that they *converge* at the optic nerve *exit*, where the LAYER OF NERVE FIBRES is thickest, and decreases as the ora serrata is approached.

11. The INTERNAL LIMITING MEMBRANE is formed by the fusion of the inner ends of Müller's fibres.

There are three important areas in the retina: 1. the OPTIC NERVE EXIT, OPTIC PAPILLA, or BLIND SPOT; 2, the MACULA LUTEA, or YELLOW SPOT, and 3, the ORA SERRATA.

1. In the BLIND SPOT, only the layer of nerve fibres is pres-

ent. It lies about one-eighth of an inch to the nasal side, and about one-tenth of an inch below the optic axis. In the center is usually a shallow depression; around the edge it is raised and forms the PAPILLA NERVI OPTICÆ.

2. The YELLOW SPOT is not in the direct visual axis. The color is due to the presence of a diffuse yellow pigment. Its edge is raised, owing to the great thickness of the *inner ganglionic layer*. From the edge to the center, all the layers decrease and disappear, so that in the center, the FOVEA CENTRALIS, the *cones alone are present. Here vision is most acute.*

3. At the ORA SERRATA all of the neural layers end abruptly, and are continued as a single layer of cuboidal or columnar cells. Beyond this point, *there is no vision.*

The light rays falling upon the retina are not transmitted to the brain by a direct route. The impressions are received by the *rods and cones*, which send impulses to the *outer reticular layer;* here the impulses are received by the processes of the *outer ganglionic layer*, conveyed through the bodies of the cells of that layer to the *inner reticular layer;* here they are relayed to the processes of the cells of the *inner ganglionic layer* and to its cells and thence to the *nerve fibre layer;* the latter makes up the optic nerve by means of which the impulses are then conveyed to various parts of the brain.

The **Optic Nerve** consists of a single bundle of nerve fibres that possess no neurilemmæ. It is said to contain from 450,000 to 800,000 nerve fibers. It is surrounded by the dura, arachnoid, and pia, continued from the brain. The lymph spaces included within these, communicate with those of the eyeball. The dura and pia pass over into the sclera, but the arachnoid, as such, is lost before this occurs; as a result, the two lymph spaces between these three layers become one. The nerve fibres penetrate the sclera through

the LAMINA CRIBROSA. As they pass through this coat, they lose the myelin sheath, so that they become amyelinated fibres when they connect with the retina.

VITREOUS BODY AND LENS.

Of the REFRACTIVE MEDIA of the eyeball, the **Vitreous** and **Aqueous Humors** and the **Lens** are yet to be described.

The **Vitreous Humor,** or **Body,** occupies the optic cup, or VITREOUS CHAMBER. This body consists of a fine limiting membrane, the HYALOID MEMBRANE, a delicate homogeneous structure enclosing the substance of the organ, which is composed of about 98 per cent. water and 2 per cent. solid elements. The latter comprise connective tissue and wandering cells, and some fibrils.

This organ is traversed by a small canal, called the CANAL OF STILLING, or HYALOID CANAL. This extends from the optic nerve to the lens, and in intrauterine life is occupied by a branch of the retinal artery, the HYALOID ARTERY, that passes to the lens.

The **Aqueous Humor** is practically lymph. It occupies the anterior and posterior chambers, and as a refractive medium is unimportant.

The **Crystalline Lens** is a solid body, and the most important refractive medium of the eyeball. It possesses two curvatures, of which the *posterior* is the *greater*. It lies in a depression of the vitreous humor, called the PATELLAR FOSSA, and is held in position by the SUSPENSORY LIGAMENT.

The LENS consists of a *capsule*, within which lies the *lens substance*. The *capsule* is composed of delicate white fibrous tissue, and to it are attached the ligaments. This is thicker anteriorly, and seems composed of layers.

The SUBSTANCE OF THE LENS is of epithelial origin, and

consists of LENS FIBRES that are greatly elongated cells. Upon the anterior surface, just beneath the capsule, is a single layer of cuboidal cells called the LENS EPITHELIUM. At the equator of the lens, these cells lengthen, forming the LENS FIBRES, which are hexagonal, nucleated structures. The nuclei are large and oval, and lie near the middle of the fibres. Peripherally, the fibres are harder than those of the center. No cells are found posteriorly.

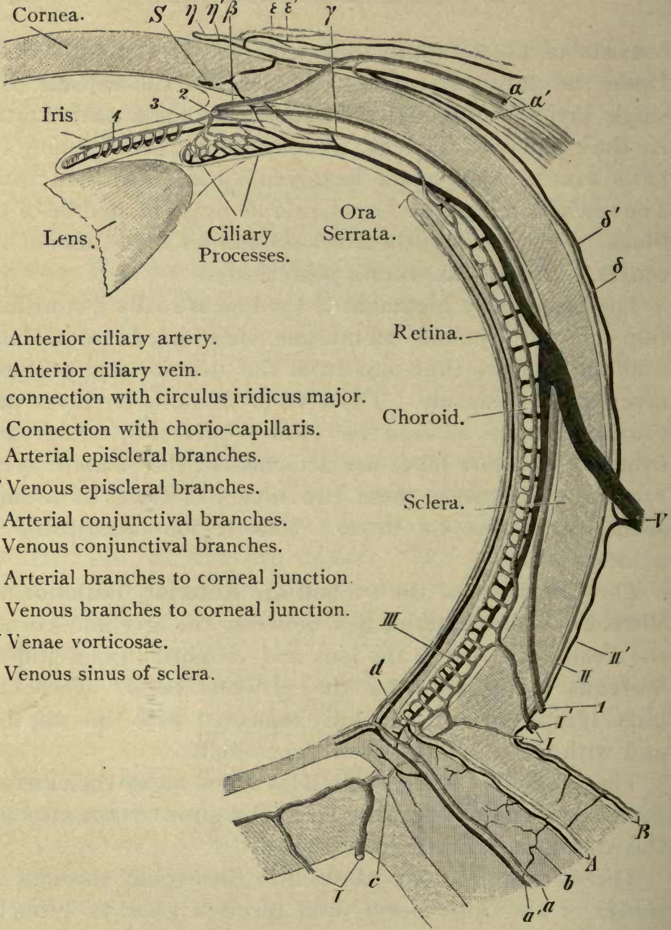
The **Suspensory Ligament** of the lens is really a continuation of the hyaloid membrane, reinforced by a large number of fibres that pass from the anterior and posterior layers of the capsule. Those from the *anterior* layer pass into *depressions between the ciliary processes*, while those from the *posterior* layer are attached to the *summits of the processes*. Between these two layers of fibres is a small space, the CANAL OF PETIT. This region constitutes the ZONE OF ZINN.

The **Chambers** of the eyeball are **Anterior, Posterior** and **Vitreous.** The **Anterior** lies between the iris and cornea, the **Posterior** between the lens and vitreous humor, and the **Vitreous** is occupied by the vitreous body. These are large lymph spaces, and are connected with one another, and with the other spaces of the eyeball.

The *circulation* of the eyeball is carried on by the CENTRAL ARTERY OF THE RETINA, the LONG and SHORT POSTERIOR and the ANTERIOR CILIARY ARTERIES.

The RETINAL ARTERY passes into the eyeball through the center of the optic nerve, and forms a *whorl* of branches upon its entrance. These vessels extend to the ora serrata. The layer of rods and cones and the macula lutea possess no blood-vessels. The blood is collected by venous stems, which form the *central vein of the retina* that has a course parallel to the artery.

The SHORT POSTERIOR CILIARY arteries are about twenty



α Anterior ciliary artery.

α' Anterior ciliary vein.

β connection with circulus iridicus major.

γ Connection with chorio-capillaris.

δ Arterial episcleral branches.

δ' Venous episcleral branches.

ϵ Arterial conjunctival branches.

ϵ' Venous conjunctival branches.

η Arterial branches to corneal junction.

η' Venous branches to corneal junction.

V Venae vorticosae.

S Venous sinus of sclera.

FIG. 95.—VESSELS OF THE EYE. External tunic, stippled; middle tunic, white; internal tunic and optic nerve, stippled criss-cross; arteries, light; veins, dark.

Central vessels of retina; *a*. artery; *a′*. vein; *b*, *c*, *d*. anastomoses with vessels of sheath, short posterior ciliary arteries and choroidal vessels, respectively.

A, inner, B, outer sheath vessels; I. short posterior ciliary artery; I′. vein; II. episcleral artery; II′. veins; III. capillaries of chorio-capillaris. 1. long posterior ciliary artery; 2. circulus iridicus major; 3. branches to ciliary body; 4. to iris (*Stöhr's Histology*).

in number. They pierce the sclera near the entrance of the optic nerve, and pass into the choroid. As they pass through the sclera, they give off branches that supply the posterior half of this coat. In the choroid, these vessels form the *chorio-capillaris*. Their branches anastomose with branches of all others, including those of the central artery of the retina.

The LONG POSTERIOR CILIARY arteries pierce the sclera near the optic nerve, and pass to the ciliary region between the choroid and sclera. At the base of the iris, they form a circle of vessels, the CIRCULUS ARTERIOSUS IRIDICUS MAJOR, which sends branches to the ciliary processes, the choroid and the iris; the latter branches pass to the pupillary region, where they form the CIRCULUS IRIDICUS MINOR.

The ANTERIOR CILIARY arteries are derived from the vessels of the recti muscles. These penetrate the sclera near the corneo-scleral junction. Their branches nourish the anterior half of the sclera, the conjunctiva, the ciliary muscle, and the anterior half of the choroid; they connect with the circulus iridicus major, and form a network of capillaries at the corneo-scleral junction. Around the optic nerve, there is some anastomosis between the branches of the ciliary arteries.

The blood is returned by the VENÆ VORTICOSÆ, which are four to six in number. These run a course entirely different from that of the arteries. Each is formed by a *whorl* of veins, and passes through the sclera to empty into the ophthalmic veins. The blood from the anterior ciliary arteries is carried by the anterior ciliary veins that run parallel to the arteries. These also receive the blood from the episcleral spaces.

The *lymphatics* are extensive, and form a series of intercommunicating spaces.

ANTERIORLY, the spaces in the cornea communicate with those of the sclera, and with the canal of Schlemm and the anterior chamber, by means of the spaces of Fontana.

The ANTERIOR CHAMBER communicates with the posterior chamber, and through this, with the canal of Petit.

POSTERIORLY, the lymphatics of the optic nerve communicate with the subarachnoidean space, on the one hand, and the hyaloid canal and perivascular spaces of the retina, on the other.

The *space of Tenon* lies external to the sclera, and receives lymph from the subscleral space, directly, and by way of the channels around the venæ vorticosæ; the lymph is sent to the spaces around the optic nerve. The latter communicate with those of the central nerve system.

The *nerves*, *long* and *short ciliary*, supply the choroid and pass between it and the sclera; at the ciliary body, they form the *ciliary ganglion plexus*, that supplies the ciliary muscle, iris and cornea and vessels. Those of the iris form a circular plexus. The nerves of the cornea have been considered.

THE APPENDAGES OF THE EYEBALL.

The **Appendages** are the **Eyelids, Conjunctiva** and the **Caruncle.**

The **Eyelid** consists of a double fold of skin, the under surface of which has become modified to form a MUCOUS MEMBRANE. This is the CONJUNCTIVA, which is composed of *stratified columnar* cells that rest upon a *basement membrane* and *tunica propria.* Among the epithelial cells some goblet cells are seen. Over its greater extent, the conjunctiva is smooth, but toward the region opposite to the free edge, folds are formed.

Beneath the tunica propria is found a dense plate of white fibrous tissue called the TARSAL PLATE (*incorrectly called cartilage*). This is wedge-shaped, with its thicker

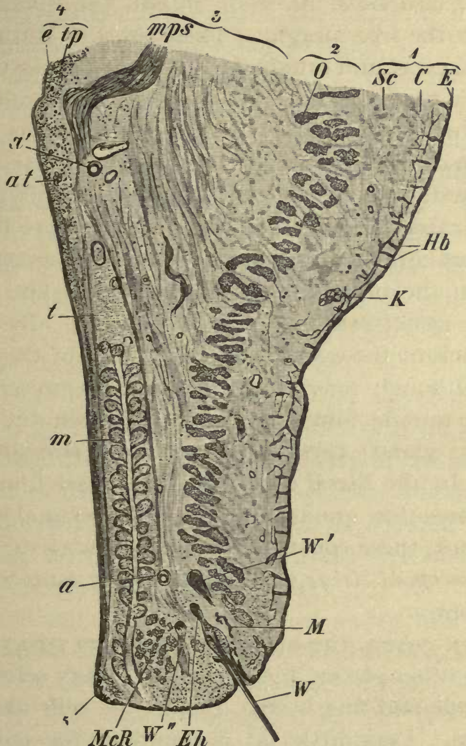


FIG. 96.—SAGITTAL SECTION OF EYELID OF A CHILD SIX MONTHS OLD (*Stöhr's Histology*).

1. Skin: *E.* epidermis; *C.* derma; *Sc.* subcutaneous tissue; *Hb.* lanugo hairs; K. sweat-glands; *W.* eyelash; *Eh.* developing lash; *W'*, *W"*. portions of follicle of eyelashes; *M.* portion of a ciliary gland. 2. Orbicularis palpebrarum muscle; O. transverse section of same; *McR.* tarsal muscle. 3. Tendon of levator palpebrarum superior; *mps.* superior levator muscle; 4. Conjunctival portion; *e.* epithelium; *tp.* tunica propria; *at.* accessory tear gland; *t.* tarsus; *m.* tarsal gland (Meibomian); *a.* arcus tarseus externus; 5. margin of eyelid.

edge at the margin of the lid. It extends a little over one-half the height of the lid, and at its end, an ACCESSORY TEAR gland is found, the GLAND OF KRAUSE. It contains a number of *compound racemose glands*, the ducts of which open upon the free margin. These are the MEIBOMIAN, or TARSAL, GLANDS, and number about thirty in the upper, and a few less in the lower lid. They resemble sebaceous glands, and the ducts are lined by stratified squamous cells. At the margin of the lid muscles fibres *marginal muscle* are seen behind the ducts. These glands secrete an oily substance that lubricates the edges of the lids, prevents them from uniting, and ordinarily keeps the tears from overflowing.

Between the tarsal plate and the upper skin surface, is found the SUBCUTANEOUS FIBROUS TISSUE. In this layer is the muscle of the eyelid, which is chiefly of the voluntary variety, although some smooth muscle is present. Some voluntary muscle fibres are found between the cilia and Meibomian gland; these constitute the *musculus ciliaris Riolani*. In the tarsal connective tissue are found smooth muscle fibres that are attached to the proximal end of the tarsal plates; these constitute the LID-MUSCLE OF MUELLER. *Diffuse lymphoid tissue* is seen in varying quantities in the tunica propria.

The SKIN covers the outer surface. Its structure is the same as in other places, and it contains many sebaceous and sweat-glands and fine hairs. Pigmented cells are found in the corium. Very little fat is found in the loose subcutaneous tissue.

At the edge of the lid, are seen two rows of heavy hairs, the CILIA, or EYELASHES. They pass deeply into the corium, and last about four months. Between the cilia and the ducts of the Meibomian glands, are some *coiled tubular* structures called the GLANDS OF MOLL. These are CERUMINOUS GLANDS, and resemble those of the external ear.

Their ducts at times are seen to open into the follicles of the cilia.

The skin at the conjunctival margin forms an acute angle, while above the ciliary region the angle is obtuse. This serves to distinguish these two margins.

The **Conjunctiva** lines the under surface of the eyelid, and is then reflected over the eyeball from the insertion of the muscles to the cornea. Here the stratified cells alone continue upon this organ. It consists of *stratified columnar* cells, *basement membrane* and *tunica propria*. In the latter lymphoid tissue is often present in abundance.

At the inner angle, or CANTHUS, of the lids is seen, in lower animals, a THIRD EYELID. This is called the PLICA SEMILUNARIS, or MEMBRANA NICTITANS. In lower forms, a *distinct tarsal plate is present*, which is seldom present in man. Here it is usually a small fold, covered by *stratified squamous* cells, in which some glands may be found.

The **Caruncle** is a little patch of skin at the inner canthus. It contains hair follicles, sweat-glands, adipose and muscle tissues within its corium, and is covered by *stratified squamous* cells. A little voluntary striated and some smooth muscle tissues are present.

Within the eyelid, *two arterial arches* are formed, one at the upper edge of the tarsus, the *external*, and the other at the edge of the lid, the *internal*. These arches are produced by the vessels coming from the inner and outer canthi. The smaller branches pass to the glands and conjunctiva of the lid, where they form delicate plexuses.

The *lymphatics* form a close, delicate plexus beneath the conjunctiva, and a loose set at the upper margin of the lid, that communicate with each other. The branches of the latter possess valves.

The *nerves* give off branches to the muscles and skin, and then form a plexus beneath the conjunctiva. The latter

supplies the glands, cilia and conjunctiva, forming, in the latter, a subepithelial plexus and sensor organs, such as CONJUNCTIVAL CORPUSCLES and BULBS.

THE LACRIMAL APPARATUS.

The **Lacrimal Apparatus** consists of the **Lacrimal Gland,** the **Canaliculi,** the **Lacrimal Sac** and the **Nasolacrimal Duct.**

The **Lacrimal Gland** is a *compound tubular* organ of a serous character. Like the mammary gland, it is a *multiple compound gland*, as it is composed of six or seven individual glands merely bound into one mass. Each has its own duct that opens upon the conjunctival surface.

Each **Gland** is covered by a delicate CAPSULE of white fibrous tissue that divides it into LOBES and LOBULES. The LOBULES consist of the TUBULAR ACINI, which are lined by *simple cuboidal cells.* The protoplasm of these is granular, and the nuclei have a basal position. These cells rest upon a *basement membrane*, which is supported by interstitial connective tissue of a fibro-elastic nature. The ducts are lined by simple columnar cells.

The *blood-vessels* are numerous and form close capillary plexuses around the tubular acini.

The *nerves* form a subepithelial plexus, but the exact mode of ending is not known.

Each **Canaliculus** has a lining of *stratified squamous cells* that rest upon the *tunica propria* and fibro-elastic layer. Outside of the tunica propria is seen some *voluntary striated muscle*, chiefly longitudinally arranged.

The opening of the canaliculus is called the *puncta*, and at this point some of the muscle fibres are circularly disposed, forming *sphincter* muscles.

The **Sac** and **Duct** are lined by *stratified columnar cells.* In the *tunica propria*, considerable diffuse lymphoid tissue

is found. Occasionally, in the lower end of the duct, *ciliated epithelial cells* are present.

Within the orbit, the eyeball is surrounded by a serous membrane called the *capsule of Tenon.* The space enclosed is the *space of Tenon,* or the *episcleral lymph space.* This space aids in the movement of the eyeball.

CHAPTER XIX.

THE EAR.

The **Ear** is made up of three parts, the **External, Middle** and **Internal.**

The EXTERNAL EAR receives the sound waves and conducts them to the MIDDLE EAR. The vibrations of the DRUM are carried across the middle ear and conducted into the INTERNAL EAR, where they are translated into the proper nerve impulses and conveyed to the temporal lobe.

The **External Ear** consists of the **Pinna** and a short **Canal,** the **External Auditory Canal.**

The **Pinna** is covered upon both sides by skin and in its center possesses a mass of ELASTIC CARTILAGE. It is very irregular, but adapted to catch sound waves. The skin possesses hair follicles and sebaceous glands. The LOBE, the lower soft portion, contains no cartilage and is very vascular.

The **External Auditory Canal** consists of OUTER, CARTILAGINOUS and INNER, BONY portions. The OUTER part is lined by skin, in the corium of which are found CERUMINOUS GLANDS. These are *coiled tubular* organs that form the wax. Hairs are very abundant here. In the INNER, or OSSEOUS, portions, hairs and glands are absent, and the tunica propria is closely attached to the periosteum of the bone. The uppermost layers, at least, of the epithelium that lines the external auditory canal moves constantly from within, outward. By this means the cerumen is ordinarily moved to the outlet.

The **Tympanic Membrane,** or **Drum,** separates the

MIDDLE from the EXTERNAL EAR. Externally, it is covered by *stratified squamous* cells continued from the skin. In this location, the stratum corneum is nucleated, and the corium is thin, except in the region of the handle of the malleus. The *middle* portion consists of white fibrous tissues arranged as RADIAL, or EXTERNAL, and CIRCULAR, or INTERNAL fibres.

The *former* becomes thinner toward the center of the tympanum and disappears entirely. The CIRCULAR fibres are more numerous externally, and become thinner toward the handle of the malleus, where they disappear. Between these two layers is a small amount of loose connective tissue. *Peripherally*, the fibrous layer becomes thickened to form the ANNULUS FIBROSUS. The *internal* surface is covered by *simple squamous*, or *columnar* cells that rest upon a *basement membrane*. In the flaccid area of the drum, the middle layer is absent, so that the internal and external layers touch each other.

The **Middle Ear,** or **Tympanum,** is an irregular cavity within the bone and is connected with the pharynx by the **Eustachian Tube.** This maintains an equal pressure upon both sides of the membrane. The mucous membrane lining these portions is covered by *pseudo-stratified ciliated epithelium.* The cilia are absent upon the EAR BONES, LIGAMENTS and MEMBRANA TYMPANI. Small *mucous glands* are found in the tunica propria. The ANTRUM and MASTOID CELLS are lined with low *polygonal cells.*

The **Ear Bones** are the MALLEUS, INCUS and STAPES. These are small masses of osseous tissue, by means of which the sound waves are transmitted from the drum to the internal ear. In the thickest portions they possess Haversian systems. Their articular surfaces are covered with hyalin cartilage. The stapes alone possesses a marrow cavity.

The MEMBRANE closing the FENESTRA ROTUNDA that leads to the internal ear consists of connective tissue. Its middle ear surface is covered by *nonciliated cells*, while that which lies in the internal ear is covered by *endothelial cells*.

The OSSEOUS portion of the EUSTACHIAN TUBE is lined by a thin mucous membrane that is closely adherent to the periosteum. The lining cells are *pseudo-stratified ciliated* elements. Glands are absent. In the CARTILAGINOUS portion, the mucosa is thicker, and is lined by *stratified ciliated cells*, among which there are a large number of goblet cells. In the tunica propria, mucous glands and diffuse lymphoid tissue are seen, and the latter may be formed into solitary follicles near the pharyngeal end.

The *blood supply* to the tympanic membrane is important. Its external surface is supplied by capillaries derived from the vessels of the external canal, while the inner surface receives vessels from those of the middle ear. The mucosa of the Eustachian tube receives blood from both the middle ear and pharyngeal vessels.

Lymphatic vessels follow those of the circulatory system. Those of the external surface of the membrana tympani empty into those of the external canal, while those of the inner surface empty into those of the tympanum. The latter lie in the deeper portions of the tunica propria, and at intervals possess dilatations.

The *nerves* of the external surface of the tympanic membrane are derived from the auriculotemporal; in addition to these, fibres enter at the edge. Both form a close plexus. This supplies the external surface by a subepithelial plexus. The inner surface is supplied by the tympanic plexus, which sends branches to the epithelial layer. Occasionally, minute ganglia are present. The Eustachian tube receives fibres from the tympanic, as well as from the pharyngeal plexuses.

THE INTERNAL EAR.

The **Internal Ear,** or **Labyrinth,** consists of **Sacculus, Utriculus, Semicircular Canals** and **Cochlea.**

The **Labyrinth** consists of the OSSEOUS and MEMBRANOUS portions, which are separated from each other by a lymph space. The BONY LABYRINTH surrounds the MEMBRANOUS portion, and is separated from it by the PERILYMPH. Within the membranous part is the ENDOLYMPH.

SACCULUS AND UTRICULUS.

The **Sacculus** and **Utriculus** are two cavities of unequal size, which do not communicate with each other directly, but with the DUCTUS ENDOLYMPHATICUS by two small canals. The **Sacculus** is the smaller, and lies anterior to the utriculus. The **Utriculus** is connected with the semi-circular canals, while the sacculus communicates with the cochlear portion of the membranous labyrinth by means of the DUCTUS REUNIENS.

The bony walls are covered by periosteum, which is lined by a layer of endothelial cells continued over the trabeculæ, that extend from the periosteum to the membranous labyrinth. From this point the endothelium continues over the external surface.

The walls of the membranous saccule and utricle are composed of bundles of white fibrous tissue arranged into two layers of variable thickness, 5 to 15 microns. The thickest portions are where the nerve fibres leave the maculæ acusticæ and maculæ cribrosæ. The cells lining these vesicles consist of *simple polygonal* epithelium, 3 to 4 microns in height, except over the MACULÆ ACUSTICÆ, where they are of the NEURO-EPITHELIAL variety. Upon approaching these areas, the polygonal change to *cuboidal* and become progressively higher until a height of 30 microns is reached.

These cells are of two varieties, SUSTENTACULAR, or SUPPORTIVE, and SPECIAL, NEURO-EPITHELIAL, or HAIR-CELLS.

The SUSTENTACULAR cells are very long, irregular columns, the basal portions of which are branched. The large nuclei, located at various levels in the inner half of the cell, produce a bulging of the cell-body. The granular protoplasm possesses PIGMENT GRANULES of a yellowish color.

The SPECIAL, or HAIR-CELLS, are also columnar, but not as long as the preceding, and extend through only one-half of that layer. The basal portion of these cells is broad, and contains large round nucleus. The distal end is rounded and possesses a cuticular border, the CUPOLA, from which projects a CONICAL CILIUM 20 microns long. This extends into the endolymph. Closer examination shows that the cilium consists of many finer hairs. The protoplasm of these cells is granular and contains a yellowish pigment.

The **Otoliths** are small, prismatic calcium carbonate crystals, 1 to 15 microns long, occurring in the vesicles, and imbedded in a gelatinous substance, the *otolith membrane*, that covers the neuro-epithelial cells. This *otolith membrane* contains many of these prisms.

The **Ductus Endolymphaticus** and its dilated extremity, the **Sacculus,** have the same structure as saccule and utricle.

A *plexus of nerve fibres* is found beneath the neuro-epithelium. The fibres extend into the epithelial layer, and as they pierce the basement membrane, the myelin sheath blends therewith, and leaves the dendrite free. These latter form fibrillæ that are connected with the neuro-epithelial (hair) cells; some pass higher between the supportive cells.

In these areas, the *capillary plexuses* are especially numerous.

THE SEMICIRCULAR CANALS.

The **Membranous Semicircular Canals** are united to the periosteum by TRABECULÆ, as in the preceding, and the endothelial cells pursue the same course in the lymph space. The epithelium resembles that of the saccule and utricle, being polygonal, but slightly larger, varying from 12 to 16 microns. Specialized areas, CRISTÆ ACUSTICÆ, are found in the floor of the AMPULLÆ (dilated portions at the junctions of the canals). Here the thickened fibrous wall forms the TRANSVERSE SEPTUM. The specialized areas resemble those of the saccule and utricle. The hairs of the neuro-epithelial cells are unusually long, some reaching to the middle of the lumen. They are called the AUDITORY HAIRS, and arise from the CUPOLA of the cells.

The *nerve* fibres pass to the thick TRANSVERSE SEPTUM, and form a plexus from which finer fibres follow the same course as in the saccule and utricle.

The *blood-vessels* are distributed in the same manner.

THE COCHLEA.

The **Cochlea** consists of a SPIRAL BONY CANAL that winds around the central, vertical AXIS, or MODIOLIS. The bony canal is separated into an UPPER, the SCALA VESTIBULI, and a LOWER, the SCALA TYMPANI. These divisions are further separated by a central shelf of bone called the LAMINA SPIRALIS. This extends about half of the way across, and the BASILAR MEMBRANE completes the partition. At the upper end of the cochlea, these canals communicate with each other; both contain the PERILYMPH.

The **Ductus Cochlearis,** or **Scala Media,** is a delicate, triangular, membranous canal that lies in the **scala vestibuli**; its outer basal angle is attached, *externally*, to the outer wall, and the inner angle, *internally*, to the lamina

spiralis. It contains the endolymph, and has an important epithelial lining. The BASILAR MEMBRANE separates it from the SCALA TYMPANI, and the MEMBRANE OF REISSNER from the SCALA VESTIBULI. The *latter* membrane is quite thin, about 3 microns, and extends from the lamina spiralis (internal to the crista) to the bony wall of the scala vestibuli at an angle of about 45 degrees. Upon its VESTIBULAR

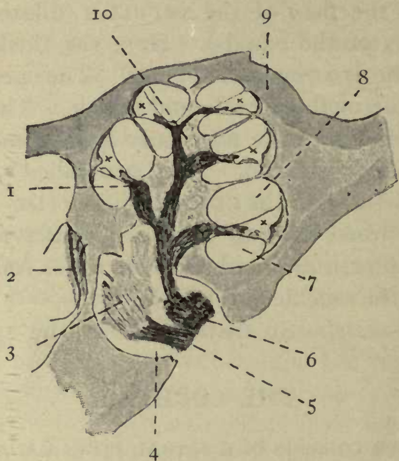


FIG. 97.—HORIZONTAL SECTION THROUGH PETROUS BONE OF A KITTEN (*Stöhr's Histology*).

1. Ganglion spirale; 2. macula; 3. ganglion vestibulare; 4. meatus acusticus internus; 5. vestibular, and 6. cochlear divisions, respectively, of the acoustic nerve; 7. scala tympani; 8. scala vestibuli; 9. bone; 10. modiolus. x. scala media.

WALL, it is covered by a layer of *pigmented endothelial cells* which rest upon the middle connective tissue layer, in which capillaries are found. The epithelial lining of its inner surface consists of a single layer of *polygonal cells.* The OUTER WALL of the scala media, for about two-thirds of its distance from the upper angle, is covered by *cuboidal cells*, within which there are quite a number of capillaries,

a *very unusual condition.* This is the STRIA VASCULARIS. At the lower margin of the latter is a small projection, the PROMINENTIA SPIRALIS; this, with the lower part of the outer wall, is covered by flattened cells that become columnar as the basilar membrane is reached. The tissue external

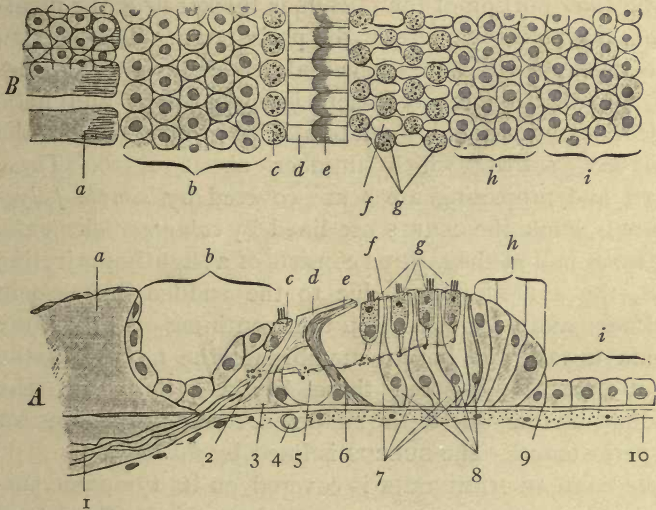


FIG. 98.—SCHEME OF THE STRUCTURE OF THE TYMPANIC WALL OF THE DUCT OF THE COCHLEA (*Stöhr's Histology*).

A. Side view; *B*. surface view. *a*. auditory teeth; *b*. epithelium of sulcus spiralis; *c*. inner hair cells; *d*. inner head plates; *e*. outer head plates; *f*. phalanges; *g*. outer hair cells; *h*. cells of Hensen; *i*. cells of Claudius. 1. Nerve; 2. first spiral cord; 3. inner pillar cells; 4. vas spirale; 5. tunnel; 6. outer pillar cells; 7. Nuel's spaces; 8. Deiter's cells; 9. membrana basilaris; 10. tympanal lamell1.

to these cells is quite thick, and extends over the vestibular wall above the attachment of Reissner's membrane, and below the attachment of the basilar membrane. This is the LIGAMENTUM SPIRALE. At the attachment of the basilar membrane this ligament forms a projection called the CRISTA BASILARIS.

The FLOOR of the ductus cochlearis (tympanic side) consists of the BASILAR MEMBRANE that unites the SPIRAL PROMINENCE to the spiral lamina; this is completed by the LIMBUS that extends from the end of the spiral lamina to the attachment of Reissner's membrane.

The *outer* portion of the LIMBUS is thicker near the membrane, due to an increase in the periosteum. This portion contains clefts and depressions that deepen toward the inner half, at which point the cleft is quite deep, and little projections, separated by lateral clefts, give rise to the AUDITORY TEETH, which number about 2,500. These TEETH and projecting areas are covered by *simple polygonal cells*, while the CLEFTS are lined by *columnar* elements. The *inner* half of the LIMBUS consists of a slightly projecting mass, the SUPERIOR LIP, due to the sudden decrease in thickness, and a lower portion that continues over the bony lamina toward the basilar membrane; the LATTER is the INFERIOR LIP. Between these lies a little space, the SULCUS SPIRALIS, due to the sudden decrease in thickness of the periosteum. The SULCUS is lined by *flat cells*.

The BASILAR MEMBRANE is covered on its tympanic surface by the TYMPANIC LAMELLA, made up of spindle-shaped cells and delicate fibres, representing an incomplete change to endothelial cells. This is continuous with the periosteum of the scala tympani. Above this layer is the *membrana propria*, that represents a greatly hypertrophied basement membrane and seems to support the epithelium upon its upper surface. The outer end of the basilar membrane is covered by the CELLS OF CLAUDIUS that continue toward the outer wall and pass into columnar and flattened elements that are found upon the basilar crest. These cells possess spherical nuclei imbedded in a slightly granular and pigmented protoplasm; they represent a continuation of the CELLS OF HENSEN. Between the limbus and the cells of

Claudius lies the ORGAN OF CORTI; composed of NEURO-EPITHELIAL and SUSTENTACULAR CELLS. This organ is divided into an inner portion, the MEMBRANA TECTORIA, and an outer part, the ZONA PECTINATA.

The CELLS of the **Organ of Corti** are the PILLAR, HAIR and SUSTENTACULAR CELLS.

The PILLAR CELLS are peculiar *S-shaped* elements possessing a striated body, surrounded by a narrow band of protoplasm. The latter is thickened at the base (*tunnel side*), and in this part is seen the nucleus. The lower end rests upon the basilar membrane, and is expanded to form the FOOT; the upper end likewise undergoes an expansion, termed the HEAD. These cells form two rows, inner and outer; they articulate above, and form a triangular canal called CORTI'S TUNNEL. This contains a semi-solid intercellular substance. The inner cell, being shorter, is more nearly vertical, and its head bears an *articular facet* for the reception of the *articular head* of the outer cell. The inner cells are more numerous and thinner than the outer, about 6,000 to 4,500, respectively. The head process of both cells continues externally as a thin, shelf-like process called the HEAD-PLATE. Of these, the INNER HEAD-PLATES lie *above*, but are *shorter* than the OUTER. The outer are called the PHALANGEAL PROCESSES, and by their union with the CELLS OF DEITER, form the MEMBRANA RETICULARIS.

The NEURO-EPITHELIAL CELLS are distributed upon the inner and outer surfaces of the pillar cells. They are the HAIR CELLS, and of these there are two rows, INNER and OUTER. Like the hair cells of the preceding, and the neuro-epithelial cells of the nasal mucous membrane, they are about half the length of the sustentacular, or pillar cells, and are columnar elements containing a granular protoplasm and an oval nucleus. The outer end has a cuticular border, from which about twenty hairs extend. The OUTER CELLS

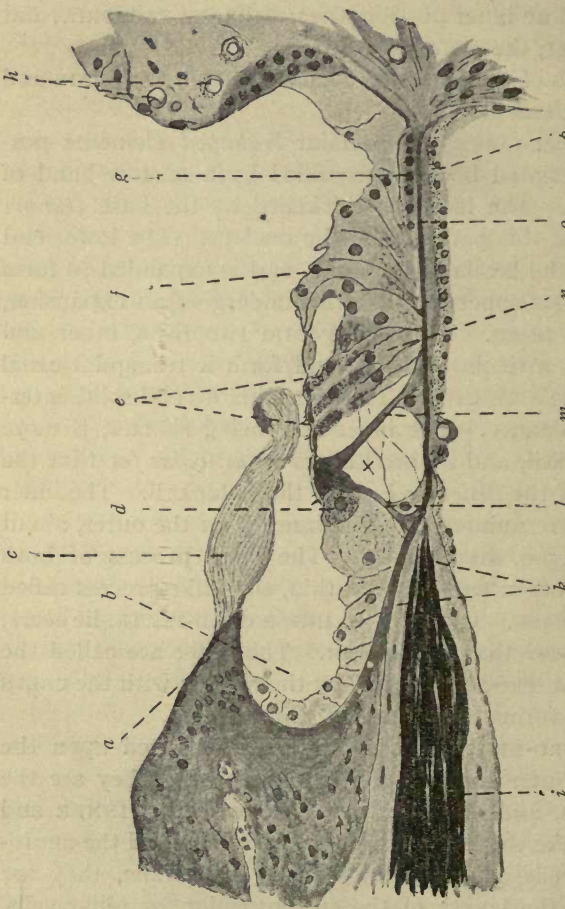


FIG. 99.—CORTI'S ORGAN. × Tunnel of Corti traversed by nerve fibres (*Stöhr's Histology*).
a. Labium vestibulare; *b.* sulcus spiralis; *c.* membrana tectoria; *d.* inner hair cells; *e.* outer hair cells; *f.* cells of Hensen; *g.* cells of Claudius; *h.* capillaries of stria; *i.* nerve bundle; *k.* labium tympanicum; *l.* inner pillar cells; *m.* outer pillar cells; *n.* cells of Deiter; *o.* membrana basilaris; *p.* tympanal lamella.

are longer and narrower than the INNER, and more numerous. Usually one hair cell is present for each two pillar cells. The outer hair cells are found in three or four rows, which are separated by the ends or phalanges of Deiter's cells and the membrana reticularis. The inner row rests upon the outer pillar cells; the cells of the next row lie opposite to the rods, and the third row alternates, producing a peculiar *checker-board* appearance, the ends of the hair cells being separated from one another by the ends of the Deiter cells.

The SUSTENTACULAR, or DEITER CELLS are INTERNAL and EXTERNAL. Each cell consists of a thin PYRAMIDAL PROCESS and a large BASAL part that contains the nucleus. The INTERCELLULAR SPACES OF NUEL, between the cells of the organ of Corti, contain a substance like that in the tunnel of Corti. Internally, DEITER'S cells pass through the entire layer, and are continuous with the cells of the sulcus. Externally, they form the phalanges that help produce the membrana reticularis. A surface view will show both sustentacular and neuro-epithelium; a basal view, however, will show only sustentacular elements. Just external to the Deiter cells are other sustentacular elements, the CELLS OF HENSEN. These extend to and continue with those of Claudius. Extending over the organ of Corti and arising from the upper lip of the limbus is a membrane composed of delicate fibres and interfibrillar substance. This is the MEMBRANA TECTORIA, or CORTI'S MEMBRANE. At one time this was part of the cells beneath, those of the sulcus and auditory teeth; it represents a *cuticular border*.

The divisions of the *auditory nerve* are *vestibular* and *cochlear*. The *vestibular* arises from the *sacculus*, *utriculus*, *maculæ* and the *semicircular canals* (*cristæ*). The *cochlear* portion arises in the *cochlea*, and is made up as follows:

In a little bony canal in the lamina spirale is a strip of gray substance that is called the GANGLION SPIRALE. This consists of bipolar cells, one branch, the *dendrite* of which passes outward into the organ of Corti, while the other, the *axis cylinder*, passes through a minute canal in the axis to the central canal, where it meets other fibres from different levels. These pass to the base and to the internal auditory meatus, as the COCHLEAR BRANCH, and then to the oblongata. The dendritic branches of these ganglion cells form a plexus in the minute canal of the spiral shelf. Toward the organ of Corti the lamina is pierced by many canals called the FORAMINA NERVOSA through which numerous fibres, the myelinated dendritic branches, pass, along its inner epithelium, to the organ of Corti. Upon entering these canals, the myelin sheaths and neurilemmæ are lost, and the naked dendrites, in bundles, continue. Each bundle separates into two, one of which remains at the inner surface and the other passes along the outer side of the pillar cells. The latter lies in the tunnel. Other dendrites cross the tunnel and pass to the outer side of the outer pillar cells and form several bundles between the Deiter cells. From these various bundles, fibrillæ connect with the hair cells.

The *blood-vessels* follow the nerves, those of the utriculus and sacculus follow the vestibular branch and those of the cochlea the cochlear division. After giving off branches to the first turn, the main trunk enters the canal of the axis, from which the branches form the peculiar GLOMERULI COCHLEÆ. Branches of the latter penetrate the scala vestibuli, and supply the limbus and neighboring tissues. Other branches continue over the vestibule to the *ligamentum spirale*, the *stria vasculare*, and *basillar membrane* surrounding the scala vestibuli. The veins surround the scala tympani and form a trunk below the spiral ganglion.

CHAPTER XX.

THE SENSES OF SMELL, TASTE, AND TOUCH.

THE ORGAN OF SMELL.

The **Nasal Mucosa** is divided into RESPIRATORY and OLFACTORY portions. The *lower* portion of the RESPIRATORY area, called the VESTIBULE, is lined by *stratified squamous cells* to the inferior turbinate bone. Here a great many hairs, sebaceous and mucous glands that extend for a short distance, are encountered. Above the turbinate, the epithelium is of the *stratified ciliated* variety, and many goblet cells are present. The *tunica propria* contains much lymphoid tissue and a large venous plexus. Mucous and serous glands are also present in great numbers in the region of the inferior turbinate and nasal septum. The mucosa is 4 mm. thick in this area.

The OLFACTORY MUCOSA is usually prominent on account of its yellow color, but this does not indicate the entire olfactory membrane. It is very thick, and ciliated cells no longer exist. The epithelium is of three varieties, the SUSTENTACULAR, NEURO-EPITHELIAL ELEMENTS and BASAL cells.

The SUSTENTACULAR cells are irregular, and possess an OUTER SEGMENT, *peripheral*, which is cylindrical, and an INNER, *basal*, that is narrow and irregular. The OUTER SEGMENTS form a row of columnar elements. The oval nuclei form a regular band or row. The protoplasm contains granules and pigment near the inner end, the former

being arranged in rows. A *cuticular border* is present, and forms the MEMBRANA LIMITANS OLFACTORIA. The inner segments are irregular, and usually branch at their internal ends.

The NEURO-EPITHELIAL ELEMENTS consist of peculiar, inconspicuous strips of protoplasm possessing an enlargement near the middle, in which lies a large, round nucleus. The latter form a band or zone of spherical elements. The outer ends of the rods extend to the free surface, between the supportive cells, while the inner ends pass to the basement membrane.

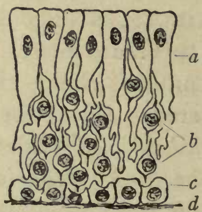


FIG. 100.—DIAGRAM OF OLFACTORY MUCOSA.
a. Sustentacular cells; *b*. neuro-epithelial elements; *c*. basal cells; *d*. basement membrane.

The BASAL cells are small and irregular elements that send processes between the upper layers and, internally, rest upon the basement membrane.

The *tunica propria* consists of a loose network of fibro-elastic tissue. This supports the mucous (BOWMAN'S) glands, whose functionating epithelium possesses a brownish pigment. These glands are numerous, forming a continuous layer.

The **Accessory Cavities** possess a lining of *ciliated cells*. The mucosa is very thin, .02 mm., and it is firmly attached to the periosteum. Glands are very few in the mucosa of these cavities.

The *blood-vessels* are numerous. The arterial branches form a dense subepithelial plexus, including a network around the glands. The veins are large in number and size, especially upon the inferior turbinate.

The *lymphatics* lie in the lower part of the tunica propria; in the olfactory area, an extra set of vessels occurs in the superficial portion. These communicate with the channels around the nerves.

FIG. 101.—ISOLATED ELEMENTS OF THE OLFACTORY MUCOSA.
a. Neuro-epithelial cell; *b.* sustentacular cells showing cuticular border.

The *nerves* are those of *ordinary* and *special sensation.* The *former* are derived from the *trigeminus* and do not connect with the cells. The *latter* form the *olfactory nerves.* The fibres of the olfactory nerves arise from the neuro-epithelial elements in the form of delicate fibrillæ; the latter join together, beneath the epithelial layer, to form small bundles that are surrounded by *perineural lymphatic sheaths;* from this position in the tunica propria they pass through the openings in the cribriform plate of the ethmoid bone and terminate around the *glomerular cells* of the olfactory lobe. These fibres possess neither myelin sheaths nor neurilemmæ.

THE SENSE OF TASTE.

The **Sense** of **Taste** is due to the **Taste-buds.** These are not restricted to the *circumvallate papillæ* of the tongue, but are found in the *papillæ foliatæ*, in the *ventral surface of the epiglottis*, at times in the *fungiform papillæ* and in the *soft palate* and *uvula.*

The organs are barrel-shaped, and consist of two varieties of cells, the SUSTENTACULAR and the NEURO-EPITHELIAL.

The SUSTENTACULAR CELLS are the OUTER, and are composed of a cell-body and a pointed end. The latter, with its

FIG. 102.—TASTE-BUD FROM A PAPILLA FOLIATA OF A RABBIT.
1. Epithelium; 2. tunica propria; *a*. taste-bud; *b*. gustatory hairs; *c*. gustatory pore.

neighbors, forms an opening at the exposed end of the organ called the GUSTATORY PORE. The cell-body varies in its thickness and the enlargement may be central or proximal. In this enlargement is seen the large nucleus.

The NEURO-EPITHELIAL elements are peculiar, long, spindle-shaped cells possessing a nuclear enlargement. This is more pronounced than that of the preceding. The peripheral end of each cell is continued as a hair-like projection through the gustatory pore; this projection is the GUSTATORY HAIR.

The nerve fibres of the *nerves of taste* arise between or upon the neuro-epithelial elements and represent the dendrites of cells in the ganglia of the glossopharyngeal

nerve and the geniculate ganglion that lies in relation with the facial nerve. These dendrites pass into the subepithelial tissue and unite to form bundles of fibres that become myelinated and join the glossopharyngeal and chorda tympani nerves. Other sensor beginnings lie in the epithelium around the taste-buds.

THE SENSE OF TOUCH.

The **Sense of Touch** is not limited to any special region, but it is best developed in certain areas, as the PALM and SOLE. It is restricted to the skin, and represents a modifi-

FIG. 103.—CORPUSCLE OF MEISSNER FROM GREAT TOE OF MAN. *n*. Myelinated nerve fibre; *h*. connective-tissue sheath; *e*. varicosities. The nuclei are invisible (*Stöhr's Histology*).

cation of general sensibility. In the papillæ of the skin, especially that of the sole and palm, are found the TACTILE CORPUSCLES OF MEISSNER.

These are elongated structures, about 50 by 150 microns, and possess transverse striations that seem due to cells with transversely placed nuclei. These are encapsulated by white fibrous tissue, and are pierced at the lower end by nerve fibres whose myelin sheaths blend with the capsule. The dendrites arise from telodendria between the cells

and possess enlargements at intervals. They pass to the bottom of the organ, and as they leave they become myelinated and covered by a neurilemma. These myelinated dendrites pass to the ganglia of the spinal and cranial nerves.

The **corpuscles of Vater,** or **Pacinian bodies,** are very large, oval structures. Each consists of a CAPSULE, an INNER BULB and a KNOB.

The CAPSULE consists of many layers of white fibrous tissue, each separated from its neighbor by a lymph space

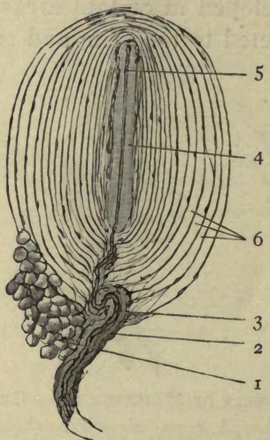


FIG. 104.—PACINIAN BODY FROM MESENTERY OF A CAT.
1. Fat cells; 2. artery; 3. nerve fibre; 4. inner bulb; 5. dendrite; 6. layers of the capsule (*Stöhr's Histology*).

lined by endothelial cells. These lamellæ are held together by an INTRA-CAPSULAR LIGAMENT that pierces all. The INNER BULB is a cylindric mass of almost homogeneous protoplasm possessing nuclei and a slight enlargement called the KNOB. The knob represents the point of origin of the dendrite that leaves this organ as a nerve fibre as in the preceding organ.

The CONJUNCTIVAL CORPUSCLES, or CORPUSCLE OF KRAUSE, are also tactile corpuscles. These are surrounded by a delicate fibrous CAPSULE, which is surrounded and lined by endothelium. The center of the corpuscle seems occupied by the divisions of the dendrite that arises here, and by lymph. Such corpuscles are found in the *conjunctiva*, *edges of the eyelids*, in the *lips* and *epiglottis*.

The GENITAL CORPUSCLES are more complex than the preceding. They may resemble the Pacinian body, or may be composed of several simple corpuscles fused into one. They are found in the glans penis and glans clitoris.

CHAPTER XXI.

DEVELOPMENT OF FACE AND TEETH.

The development of the face is a complicated process, a number of different fetal structures taking part therein. At about the twelfth day of intrauterine life there appears a depression upon the ventral surface of the blunt head-process called the ORAL DEPRESSION, or STOMODEUM. The floor of this depression sinks deeper, forming the *pharyngeal membrane*, and the margins become more pronounced. At about the fifteenth day the lower boundary of the depression becomes formed upon each side into a finger-like process, called the FIRST VISCERAL ARCH, that soon divides into a shorter upper portion, the MAXILLARY DIVISION, and a lower part, the MANDIBULAR DIVISION. The upper division forms now the lateral boundary and the lower the inferior boundary of the oral depression. At about the same time the tissues in the frontal region become projected in the form of a blunt mass between the maxillary divisions of the first arch, constituting the NASO-FRONTAL PROCESS. Thus the stomodeum has become a pentagonal fossa. At about the eighteenth day a second finger-like process makes its appearance beneath the mandibular portion of the first arch; this is followed by a third arch about the twenty-first day, a fourth by about the twenty-fourth day, and the fifth and last arch is formed by the twenty-eighth day. The last are less highly developed than the first, and while the lower ones are forming the upper ones are undergoing metamorphosis into their adult structures.

The changes that occur in the VISCERAL ARCHES will be

considered first: Each arch consists of a core of *mesoderm* containing a rod of cartilage and a blood-vessel called the *visceral arch vessel;* externally the arch is covered by *ectoderm* and internally by *entoderm.* The arches are separated from each other by a *groove* or depression, internally, and externally, and spanning the groove is the *visceral cleft membrane* consisting merely of ectoderm and entoderm, so that no real complete cleft exists in the early stages of development; in aquatic animals these membranes do rupture to form the gill-clefts. On each side there are four *external* and four *internal* visceral grooves or, better, *branchial pouches.*

The first arch, as previously mentioned, divides into two portions, *maxillary* and *mandibular;* the maxillary part unites with naso-frontal process to complete the upper jaw; it itself gives rise to the bulk of the upper jaw and most of the palate. The upper jaw is completed by about the fortieth to the forty-seventh day. The mandibular process unites with its fellow of the opposite side to form the complete lower jaw, union being completed by the end of the fifth week, or thirty-fifth day. In addition, the cartilage of the mandibular process gives rise to incus and malleus, and stylomandibular ligament.

The rod of cartilage of the second arch gives rise to the stapes, styloid process, stylohyoid ligament and lesser cornu of the hyoid bone.

The cartilage of the third arch forms the body and greater cornu of the hyoid bone.

The cartilages of the fourth and fifth arches unite and form a single mass, the thyroid cartilage of the larynx.

The first external branchial pouch persists only at its dorsal end to form here the external auditory canal. From both first and second arches in this region the ear is developed. The remaining pouches are lost as the arches

overlap each other from above downward. Occasionally part of a pouch persists as an enclosed cyst of ectoderm and this is called a *branchial cyst.* In case a pouch membrane ruptures and permits of a passage-way from the outside to the gut-tract it is called a *cervical fistula.*

The first internal pouch is formed into a tube with its outer end dilated into an irregular cavity, the *tympanic cavity;* the tube-like portion connecting this with the pharynx is called the *Eustachian tube.* That part of the first pouch membrane separating the external auditory canal from the tympanic cavity is the future *tympanic membrane*, or *ear drum.* In the middle of the ventral portion of the first pouch is found a projection, the *tuberculum impar*, which later becomes the anterior, or apical two-thirds of the tongue.

From the region of the second pouch (representing second and third arches) we find the tonsil and lateral recess of the pharynx developed, dorsally, while ventrally in the median line the middle lobe of the thyroid body is formed, and just lateral of this the dorsal, or basal one-third of the tongue by two masses (one on each side).

In the third pouch region (third and fourth arches) the thymus body, as two lobes, appears and also the inferior parathyroids and the carotid bodies.

From the fourth pouch (fourth and fifth arches) the lateral lobes of the thyroid body with the superior parathyroids.

The NASO-FRONTAL PROCESS is at first a blunt mass of tissue projecting from the frontal region. As it grows down between the maxillary divisions of the first visceral arch, it becomes thickened along its margins, forming here the *globular processes;* each process contains a little depression that constitutes the *nasal pit.* In addition, two masses, the *lateral nasal processes*, develop from the

naso-frontal process, at the orbital region, to form the lateral boundary of the nasal pits. Usually by the fortieth or forty-second day the naso-frontal process has filled the gap between the two maxillary processes of the first arch, and union of these parts is completed. As a result the nasal pits are separated from the mouth cavity. The derivatives of the naso-frontal process are the middle of the

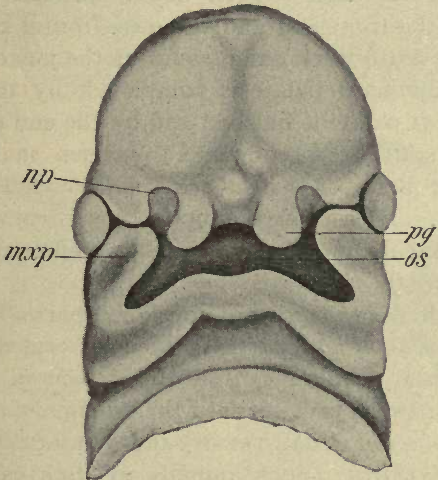


FIG. 105.—FACE OF AN EMBRYO OF 8 MM. (*McMurrich, after His*). *pg*, Globular process of naso-frontal process; *np*, nasal pit bounded externally by the lateral nasal process; *os*, oral pit; *mxp*, maxillary process of first visceral arch.

upper jaw (intermaxillary bones) the middle of the upper lip, the tip, septum, alæ and bridge of the nose and the vomer. The crevice between lateral nasal processes and the maxillary division of the first arch extends from the orbit to the nose cavity. When this crevice is closed a cord of epithelium is inclosed, and by hollowing out this cord of cells forms the naso-lacrimal duct. If the lip por-

tions of the naso-frontal process and first arch fail to unite, a *malformation, unilateral, or bilateral hare-lip,* is produced. If the bony parts within are affected, various forms of *cleft-palate* result.

The **palate** is developed in the form of three shelves, *two lateral* from the maxillary processes of the first arch and *one frontal, triangular, from the naso-frontal process.*

At about the eighth week union between the lateral shelves at the front end and the naso-frontal portions begin; by the ninth week union as far as the posterior border of the future hard palate is completed, by the eleventh week the soft palate is finished and by the end of the third month the uvula is complete. Various malformations may occur here, as *partial,* or *complete cleft-palate* and *bifid uvula.* Then after the upper jaw is completed two ridges appear upon each jaw, the *inner* represents the *gum* and the *outer* the *lip.*

The Teeth.—The teeth are developed partially (enamel) from the *ectoderm* and partially (dentin, cementum, pulp, and peridental membrane) from the *mesoderm.*

There are two sets of teeth in the mammals, TEMPORARY, or DECIDUOUS, or MILK TEETH, and PERMANENT, or SUCCEDANEOUS TEETH. Such animals are *diphyodonts.* Animals that may develop teeth successively without regard to number are *polyphyodonts.*

In the former case the teeth are unlike, and the animals are *heterodonts,* while in the latter case the teeth are all alike and the class is that of *homodonts.*

The teeth begin to develop during the *sixth week* (shortly after the completion of the lower jaw). From the under surface of the thickened epithelium of the jaw a band of epithelial cells grows into the mesodermal core of the jaw. This is the DENTAL SHELF, the earliest indication of the developing teeth. Shortly after the formation

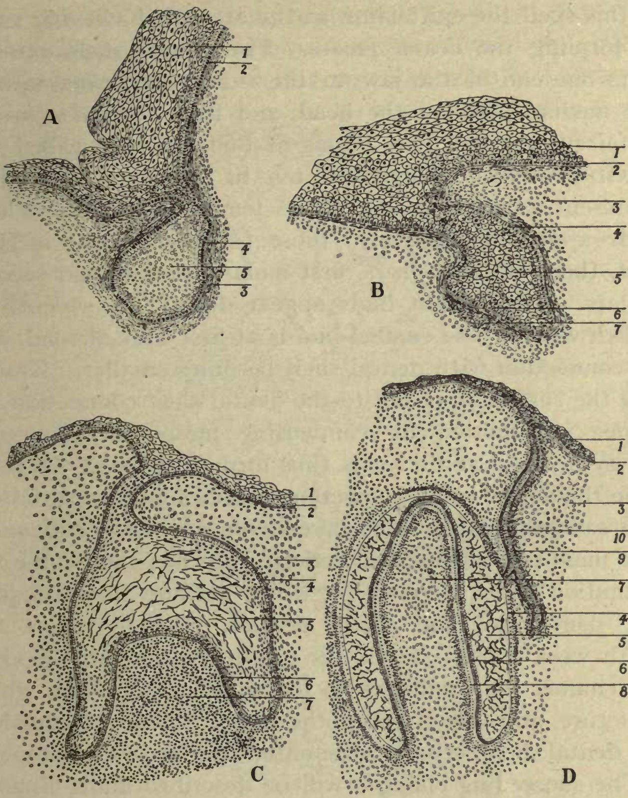


FIG. 106.—FOUR STAGES OF TOOTH DEVELOPMENT
(*After Böhm, Davidoff and Huber*).

A, Formation of the enamel from the dental shelf; B, later stage with early formation of the dental papilla; C, later stage showing enamel sac with its layers differentiating and the dental paiplla well advanced; D, enamel sac completed (just preceding enamel formation) connected to dental shelf; dental papilla completed. 1, 1, 1, 1, oral epithelium; 2, 2, 2, 2, basal layer of same; 3, 3, 3, 3, mesoderm of jaw; 4, 4, 4, 4, outer layer of enamel organ; 5, 5, 5, 5, middle layer; 6, 6, 6, inner layer; 7, 7, 7, dental papilla; 8, layeı of odontoblasts; 9, dental shelf; 10, follicular sheath.

of this shelf the epithelium at the area of thickening sinks in forming the *dental groove*. The dental shelf extends from one end of the jaw to the other and leans toward the median plane of the head, and from the *outer free* or *labial* surface ten little germs or buds develop, called the ENAMEL GERMS. There are ten in each jaw, and they represent enamel organs of the temporary teeth. These buds appear successively: those for the central incisors first, then lateral incisors, first molars, canine, and second molars. The earliest buds appear during the seventh or eighth week. The enamel bud is at first flask-shaped, and its connection with dental shelf becomes smaller. Gradually the surface opposite to the dental shelf connection becomes invaginated by condensing mesoderm; the concavity deepens and a *sac* is thus formed, while at the same time the dental shelf connection becomes more attenuated. The sac consists of three layers, *inner*, *middle*, and *outer*. The mass of condensed mesoderm that has caused the sac formation of the enamel, but which lies now in the enamel sac, constitutes the *dental papilla*. During about the tenth week mesoderm in the immediate neighborhood of the enamel sac condenses to form a sheath for the whole structure, and this is called the *dental follicle*. Meanwhile the dental shelf becomes attenuated and tends to disappear.

The succeeding changes will be described under **Enamel Formation, Dentin Formation** and **Cementum Formation.**

Enamel Formation.—The **enamel organ** now consists of three layers: the OUTER LAYER is composed of simple columnar epithelial cells continuous with the inner layer of cells at the base of the organ. They play no part in the formation of enamel. The MIDDLE LAYER consists of a mass of stellate cells varying in thickness as Fig. 107 shows; these cells make up the bulk of the enamel organ and the meshwork formed by them is filled with a fluid. This

layer likewise has nothing to do with the direct formation of enamel, but seems to have a nutrient function. Along the innermost portion of this reticular mass is a group of

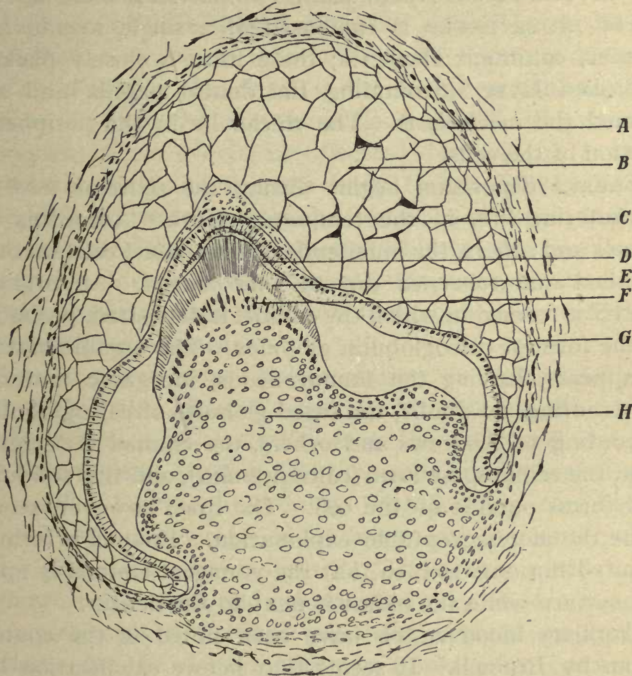


FIG. 107.—SECTION OF A DEVELOPING TOOTH OF A CAT EMBRYO. (*After Piersol.*)

A, Outer, *B*, middle, *C*, inner layers of enamel organ; *D*, formed enamel; *E*, formed dentin; *F*, layer of odontoblasts; *G*, follicular sheath; *H*, dental papilla, mesoderm

cells forming a layer called the STRATUM INTERMEDIUM. This layer consists chiefly of spherical cells mixed with some columnar elements. Apparently the spherical cells have elongated to the columnar type, probably for the

purpose of replacing cells that fail in the innermost layer. This stratum intermedium is looked upon as the reserve layer to the enamel-forming cells; the cells of this stratum are most numerous where enamel formation is most active.

The INNER LAYER is composed of a single row of tall slender, columnar elements; these form a closely packed unbroken layer surrounding the dental papilla and are termed the *ameloblasts*. The nuclei lie in the peripheral portion of the cells.

Enamel deposition begins during the *sixteenth week* of intrauterine life, in the temporary teeth. According to Tomes and others, the inner ends of the enamel cells become calcified and *converted directly into enamel*. An organic matrix is formed in which the enamel is deposited, probably in the form of calcoglobulin globules. The organic matter disappears, leaving the homogeneous, inorganic material representing, no doubt, the fused globules of calcoglobulin. According to Andrews and others, the enamel is secreted from the cell in some form (calcoglobulin), and this solidifies and forms outside of the cell. The first, however, seems to be the more acceptable explanation. Enamel is formed from within outward, so that the youngest enamel is upon the surface while the oldest is next to the dentin.

Capillary blood-vessels have been noted in the enamel organ by Bromell. It seems that before calcification begins that vessels are absent; with the formation of enamel vascularization of the enamel organ begins and is said to persist until the tooth erupts. By the time that the tooth begins to erupt, or, at the latest, when completely erupted, the enamel is fully formed.

Between the enamel organ and the surface of the dentinal papilla is a layer of homogeneous substance called the *membrana preformativa*. Reference to this will be made later.

Dentin Formation.—The **dentin** is derived from the dental papilla; this structure is composed of embryonic connective tissue in which four different kinds of cells are found. Upon the surface of the papilla will be found a single layer of flask-shaped cells, the *odontoblasts*. These form the *membrana eboris* from which the dentin is derived. The basal portion of each cell is directed toward the papilla, or centrally, and contains the nucleus. Each cell possesses processes; those which are directed toward the enamel organ constitute the ultimate *dental fibres*. These cells are differentiated shortly before the formation of dentin begins. Just beneath the layer of odontoblasts the papilla is practically devoid of cells; beneath this, however, there is a cellular area of mixed cells and then again a central area containing but few cells.

Dentin is first formed at the cutting, or occlusal surface and during the *sixteenth week* of intrauterine life. The dentin seems to be a *secretion* from the peripheral ends of the odontoblasts so that the processes in this region are surrounded by the lime salts, thus forming the *dental sheaths* and *tubules;* the odontoblasts are constantly outside of the dentin that is formed. The dentin is laid down from without inward, and in areas where dentin formation is incomplete spaces, that are called the *interglobular spaces*, remain. As the dentin becomes thicker (by encroachment upon the dental papilla) the dental fibres elongate and the tubules become correspondingly longer. The dentin in the crown portion is formed first, the root portion being completed last. When the teeth begin to erupt their roots are partially formed; by the time that the whole crown is exposed the fang is usually completed. In the case of the incisor teeth the roots are usually completed by the time that the tooth begins to erupt.

Cementum Formation.—The **cementum** is also of mesoder-

mal origin. As the enamel organ becomes invaginated by the dental papilla the mesoderm immediately surrounding the enamel organ condenses to form a sac-like covering, the DENTAL FOLLICLE. This structure gives rise to the cementum and the alveolar process of the jaw and its remains constitute the PERIDENTAL MEMBRANE. The follicle is formed shortly after the tenth week. During the earlier stages of development the dental follicle covers the entire enamel organ and is connected with the dental papilla at its base. The follicle upon its *outer* surface forms *bone*, and upon its *inner* surface forms the *cementum* of the tooth. As the enamel organ grows the follicle seems to recede from the cutting edge until the neck portion is reached; at this point it remains, and as the root is formed by the dental papilla the follicle forms the cementum until the full length of the root is reached. The process of cementum formation is like that of bone, a *secretion*, and layer are formed as described in the section on the structure of cementum. The cementum and bone of the jaw are developed from the dental follicle, or *peridental membrane*, at the expense of the latter, it becoming thinner as the cementum and alveolar bone increase in thickness.

The temporary teeth begin to erupt from the sixth to the eighth month after birth and the set is usually completed by the twenty-fourth to the thirtieth or thirty-sixth month. The order of eruption is as follows:

Central incisors, sixth to eighth month.
Lateral incisors, seventh to ninth month.
First molars, twelfth to fourteenth month.
Canines, sixteenth to eighteenth month.
Second molars, twenty-fourth to thirty-sixth month.

The **permanent teeth** are thirty-two in number. The difference in number of the two sets and later appearance

of added teeth is due to the fact that the jaw at certain periods will accommodate only a certain number of teeth, and any attempt to hurry their appearance will interfere with the dental arch. Of these permanent teeth, the *molars*, twelve in number, are *not succedaneous* teeth at all, but *primary* teeth as will be explained later. The germs for most of the permanent teeth are formed during intrauterine life.

During the *sixteenth week* a bud appears at each *end* of the dental shelves; these buds are the germs for the *first permanent molar* teeth. During the *seventeenth week* the germs for the *central incisors* appear from the *lingual* surface of the dental shelf, opposite the point of formation of the corresponding temporary tooth; the remaining succedaneous teeth follow in order of their eruption. The enamel organs undergo the same changes as previously described, with the exception that the process is somewhat slower, making their eruption somewhat later. As was stated above, the germs for the first permanent molars appear at the *ends* of the dental shelves and so have no forerunners; the germs for the *second molars* are developed from the neck of the enamel organs of the first molar during the third to the fifth month after birth; the enamel sacs for the *third* permanent molars appear from the neck of the enamel sacs of the second molars during the third to the fifth year after birth. All of the molar teeth, therefore, have no forerunners, and, are then, *primary* and *not succedaneous* teeth.

The first permanent molar tooth is the first one of the second set to appear; the order and times are as follows:

First molar, sixth year.
Central incisors, seventh year.
Lateral incisors, eighth year.

First premolars, ninth year.
Second premolars, tenth year.
Canines, eleventh to twelfth year.
Second molars, twelfth to thirteenth year.
Third molars, seventeenth to twenty-fifth year.

The eruption and succession of the teeth are by no means simple processes. As the tooth germs develop they at first lie in a groove of the jaw, covered merely by the gum; gradually transverse partitions of bone form so that the entire tooth is ultimately incased in the bone of the jaw. The bone intervening between the tooth and the gum amounts to but a thin lamella that is completed shortly before the tooth is to erupt, except in the region where the gubernaculum passes to the gum. As eruption is to take place, that bone which is last formed (toward the gum) is resorbed so that there is no interference with eruption.

The process of eruption is as follows: The bone covering the labial surface of the crown is resorbed until fully one-half of the surface is exposed; this is followed by the resorption of the bone on the lingual surface but here the process is slower and less complete, leaving some bone to protect the germs of the permanent teeth underneath. As a result of this process the crown apparently grows through the gum when in reality the gum becomes stretched over the tooth by the disappearance of the bone beneath. As the resorption continues until the crown is exposed new bone is laid down about the base of the tooth to strengthen its position. According to some writers the tooth erupts by the growth of the root forcing the crown above the gum surface. When one considers that in the temporary and permanent cuspid teeth the roots are completed by the time eruption occurs, this force cannot be counted upon as a

factor in the eruption of the teeth. It might play some part in the eruption of the other teeth, but even this is doubtful.

From the eruption of the second temporary molar tooth until the fourth year the teeth are practically quiescent. From the fourth year on the temporary teeth begin to decalcify and drop out to make room for the permanent teeth. The process of decalcification is one of absorption; it begins in the apical portion of the tooth and advances to the enamel line. The central incisors are the first affected, at about the fourth year, and the others follow in order of their eruption. As a result of this process the root becomes absorbed and the hold of the tooth upon the jaw becomes weakened; ultimately merely an enamel cap remains; this process extends over a period of about three years for each tooth, going on simultaneously or successively in the various teeth. Some claim that the process of resorption of the roots is due to the pressure exerted upon the root by the permanent tooth beneath. This does not, however, seem to be the cause, for in cases of absence of the succedaneous tooth the process of absorption of the root of the temporary tooth occurs as usual.

The permanent teeth follow the temporary successively as the latter are lost. As the jaw gradually increases in length there is a second permanent molar added at the twelfth to the fourteenth year and a third one at the eighteenth to the twenty-fifth year.

The permanent teeth erupt in the same manner as the temporary organs; that is, by the absorption of the bone from the crown portion. As this process of absorption occurs during the eruption of both sets the jaws would become thinner from above downward; to offset this nature adds below more than is absorbed above so that the dimension from above downward increases up to the prime of life.

As the second set is gradually lost bone is not replaced as rapidly as lost so that in an old jaw the alveolar processes are lost (showing the absorption from above downward) and the vertical dimension decreases.

Connected with the permanent tooth is a structure, the GUBERNACULUM DENTIS, that seems to be of importance. It is a fibrous, cord-like structure attached to the apex of the tooth-sac and ends at the epithelium of the gum. It seems to direct the follicle by its tension and also to indicate the direction of eruption, and to maintain the tooth in position.

In regard to *malformation* of the teeth, both sets may fail to appear, or the succedaneous teeth alone may not develop; again individual teeth may be absent, or a third set may appear after the second has been lost. What is more common than the latter is a duplication of some of the permanent teeth forming a row within the normal set; a fourth molar may appear if the jaw is long enough to accommodate it. Malformations of the root may be in the form of an additional root or the fusion of several to form one massive root. Again, the teeth may be united by *fusion* (if before birth) or *concrescence* (if after birth). If two teeth are found in a single sac the condition is known as *geminous teeth*.

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$\frac{1}{25}$ to $\frac{1}{30}$ inch bronchioles a Cart. muscle

$\frac{1}{50}$ cilia disappear.

Myelocyte
Nuc. red
Giant cells

Leucocytes
Basophiles
Eosinophile

always are free in alveoli

Cells of Lungs have fill lumen of alveoli

Have no granules

Cells nucleus granules

Serous cell at base

Mucous cell nucleus middle

mucus

Immediate conditions due to difference in intelligence & efficiency & is not wholly due to bad politics or bad institutions

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Artery through
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